

**U.S. DEPARTMENT OF COMMERCE
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PB-275 169

Characterization of Washington, D.C., Carbon Monoxide Problem

GCA Corp, Bedford, Mass GCA Technology Div

Prepared for

**Environmental Protection Agency, Research Triangle Park, N C Monitoring
and Data Analysis Div**

Oct 77

EPA-450/3-77-053

PB 275 169

October 1977

**CHARACTERIZATION
OF WASHINGTON, D.C.,
CARBON MONOXIDE
PROBLEM**



**U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Air and Waste Management
Office of Air Quality Planning and Standards
Research Triangle Park, North Carolina 27711**

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TECHNICAL REPORT DATA
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1. REPORT NO. EPA-450/3-77-053	2.	3.
4. TITLE AND SUBTITLE Characterization of the Washington, D.C., Carbon Monoxide Problem		5. PB275169 October 1977
		6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) Theodore P. Midurski and Victor L. Corbin		8. PERFORMING ORGANIZATION REPORT NO. GCA-TR-77-11-G
9. PERFORMING ORGANIZATION NAME AND ADDRESS GCA Corporation GCA/Technology Division Bedford, Massachusetts 01730		10. PROGRAM ELEMENT NO. 2 AA 635
		11. CONTRACT/GRANT NO. 68-02-1376 TO No. 27
12. SPONSORING AGENCY NAME AND ADDRESS U.S. Environmental Protection Agency Air Management Technology Branch Monitoring and Data Analysis Division Research Triangle Park, North Carolina 27711		13. TYPE OF REPORT AND PERIOD COVERED Final Report
		14. SPONSORING AGENCY CODE 200/04
15. SUPPLEMENTARY NOTES		
16. ABSTRACT Relationships between traffic, vehicle emissions, and carbon monoxide (CO) levels within the Washington, D.C., area are analyzed using the revised CO Hot Spot Guidelines and supplementary computer models. As such, the report provides a demonstration of the revised CO Hot Spot Guidelines, as well as a first level analysis of potential CO problems in the Washington, D.C. area. Three levels of analysis are described: (1) areawide screening of all signalized intersections, (2) hot spot verification at 29 selected locations, and (3) comparison of computer modeling results with ambient data. Data requirements and resource needs are identified for each level of analysis. Annotated instruction sheets, in addition to all tables and graphs used in the calculations, are provided. A preliminary review of the data revealed that the existing data base for the Washington, D.C., area was inadequate for developing and testing techniques for relating changes in VMT and/or vehicle emissions to changes in ambient CO levels.		
17. KEY WORDS AND DOCUMENT ANALYSIS		
a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Carbon Monoxide CO Hot Spots Hot Spot Guidelines Washington, D.C. Air Quality		
18. DISTRIBUTION STATEMENT Distribution Unlimited	19. SECURITY CLASS (This Report) Unclassified	21. NO. OF PAGES 155
	20. SECURITY CLASS (This page) Unclassified	22. PRICE PCA88-A01

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by

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Contract No. 68-02-1376

EPA Project Officer: Warren P. Freas

Prepared for

**U.S. ENVIRONMENTAL PROTECTION AGENCY
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This Final Report was furnished to the U.S. Environmental Protection Agency by the GCA Corporation, GCA/Technology Division, Bedford Massachusetts 01730, in fulfillment of Contract No. 68-02-1376, Task Order No. 27. The opinions, findings, and conclusions expressed are those of the authors and not necessarily those of the Environmental Protection Agency or of cooperating agencies. Mention of company or product names is not to be considered as an endorsement by the Environmental Protection Agency.

FOREWORD

As its first task under Contract No. 68-02-1376, Task Order No. 27, GCA/Technology Division was to evaluate the adequacy of the data base in the National Capitol AQCR for developing and testing techniques by which changes in VMT and/or vehicle emissions could be related to changes in ambient levels of oxidants and carbon monoxide. The data were to be drawn from a baseline summertime period in either 1973 or 1974 and the corresponding period in 1976. If the data base proved to be adequate, work in developing these techniques was to begin. However, at the conclusion of this task it was jointly concluded by the EPA Project Officer and GCA/Technology Division that fundamental inadequacies in the existing data bases would prevent carrying out the development and testing of such techniques at this time. Under the revised CO phase of the program that resulted from this decision, relationships between traffic, vehicle emissions, and CO levels within the Washington, D.C. area were analyzed using revised CO Hot Spot Guidelines techniques and supplementary computer simulation models. The results of these analyses are presented in this report.

The revised oxidant phase of the work became a study to characterize the Washington, D.C. oxidant problem using data collected during the summer of 1976 by the local agencies, plus data collected under a number of special programs sponsored by EPA. The results of this work are reported separately.

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ACKNOWLEDGMENTS

We would like to acknowledge the thoughtful assistance of David Barrett and George Schewe of EPA's Source Receptor Analysis Branch, Monitoring and Data Analysis Division during the course of this project. We would also like to thank the District of Columbia Department of Transportation, Bureau of Traffic Engineering and Operations, for their help in supplying us with traffic data.

SECTION I

INTRODUCTION

PROJECT OBJECTIVES

The primary objectives of the study being reported here include (1) providing insight as to the possible extent of carbon monoxide problems in Washington, D.C., and (2) providing a demonstration of the use of a three-part analytical procedure that was developed specifically for assessing localized carbon monoxide problems; this procedure is described in detail in a GCA/Technology Division report entitled Guidelines for Identification and Evaluation of Localized CO Hot Spots. Volume 1: Techniques and Workbook, hereafter referred to as the Hot Spot Guidelines.*

The nature of the study did not provide for a comprehensive analysis of all aspects of carbon monoxide in the District; rather, a preliminary investigation was made to determine whether or not there was a potential problem at each signalized intersection in the city, and a more detailed follow-up analysis was conducted at a number of individual intersections where the preliminary investigation indicated that a potential problem existed. Again, the intent of the project is, first, to provide a preliminary analysis of the areal extent of carbon monoxide problems in Washington, D.C. based on the screening procedures outlined in the Hot Spot Guidelines, and second, to report on the experience gained in applying the Hot Spot Guidelines in a large urban area (i.e., Washington, D.C.).

* The Hot Spot Guidelines used in this study are a July, 1977 draft incorporating emission estimates from Supplement 5 to AP-42. These guidelines are presently being updated to Supplement 8 emission changes. Under separate contract, the CO estimates herein for Washington, D.C. will be redone. The final report of this subsequent study will supercede this report when completed.

BACKGROUND

Carbon monoxide is a colorless, odorless, tasteless, relatively inert gas that is formed principally as a by-product of incomplete combustion. The dominant source of carbon monoxide emissions is the internal combustion engine. In fact, it has been estimated that some 76 percent of the total carbon monoxide emissions that occurred in the United States during 1972 were directly attributable to transportation sources associated with the internal combustion engine.

Definite, deleterious health effects are associated with exposure of humans to carbon monoxide, therefore it is for public health reasons that efforts are being made to reduce, where necessary, high ambient carbon monoxide concentrations. In this regard, the federal Clean Air Act of 1970 was enacted as a mechanism for establishing specific limits for ambient concentrations of carbon monoxide, and for providing the legal mandates to ensure that efforts would be expended by state and local governments to meet these limits. These limits, specified as National Ambient Air Quality Standards (NAAQS), are that 1-hour average ambient concentrations of CO must not exceed 40 mg/m^3 (35 ppm) more than once a year, and that 8-hour average concentrations must not exceed 10 mg/m^3 (9 ppm) more than once per year during nonoverlapping periods.* Experience has shown that the 8-hour standard is the more often violated.

Because carbon monoxide is a primary product of combustion, relatively inert, and released near the ground, the highest ambient concentrations are typically found in the immediate vicinity of the emission source.

* Nonoverlapping in this case implies that there are no common 1-hour time increments included in two or more 8-hour averaging periods. Thus, for a period of, say, 16 hours, there are a total of nine continuous 8-hour periods; however, only two of these periods- the first hour through the eighth hour, and the ninth hour through the sixteenth hour- are nonoverlapping.

Hence, studies of carbon monoxide problems must focus on local analyses rather than areawide analyses of the type undertaken for other pollutants like oxidants and SO₂. The highest concentrations are also most likely to occur at locations with the highest emission rates. In this regard, the locations of most interest for CO analyses are near points of heavy traffic flow or traffic congestion.

A basic problem in the analysis of CO is to identify individual hot spots (locations where the NAAQS is being violated). Until recently air quality monitoring data were considered to provide an adequate indication of whether or not an area was in compliance with the NAAQS for CO. Numerous studies, however, have indicated that CO problems are much more widespread than is indicated by the existing monitoring networks. There are several reasons for this apparent limitation in the ability of monitoring systems to provide an adequate indication of the areal extent of CO problems. First, monitoring networks to date have been rather limited with regard to the actual number of sites measuring CO, owing primarily to the high cost of equipping and operating a station. As an example, there were only five CO monitors operated in the District during 1975. Second, a monitor generally provides a direct indication of CO concentrations within the immediate vicinity of the monitor only, and it therefore may not detect localized, high concentrations of CO. Third, compromises generally are required in selecting monitoring sites so that the actual locations where measurements are being taken are not always the most desirable with regard to identifying the maximum concentrations to which the public may be exposed.

Alternatively, the trend has been to utilize various modeling procedures to identify and analyze potential hot spots. One model designed specifically for the task of identifying potential hot spot locations on an areawide scale was recently developed by GCA/Technology Division and is described in a report entitled Guidelines for Identification and Evaluation of Localized Violations of Carbon Monoxide Standards, Volume I.¹ The techniques described therein provide the means for (1) conducting a relatively simple first level analysis of an entire area to identify specific locations

with hot spot potential; (2) conducting a more detailed second level analysis of those locations identified as having hot spot potential to provide some dimension of the potential at each location; and (3) conducting a rather detailed third level analysis of selected locations using computer models to compute air quality based on traffic and meteorological parameters specific to each location. The specific techniques used in the Hot Spot Guidelines will be described in more detail later. These Hot Spot Guidelines were applied in the analysis of CO hot spots in Washington, D.C.; the specific techniques used and the results of the analysis will be described in detail in the following sections.

SECTION II

CARBON MONOXIDE MONITORING IN WASHINGTON, D.C.

MEASURED CO DATA

The existence of carbon monoxide problems in Washington, D.C. has been established through continuous air quality monitoring programs conducted by the District of Columbia's Department of Environmental Services. During 1975 and 1976, carbon monoxide concentrations were monitored at six locations throughout the city; these locations are shown in Figure 1.

During 1975, violations of the national ambient air quality standard (NAAQS) for 8-hour average concentrations of carbon monoxide occurred at all six monitoring sites and the NAAQS for 1-hour average concentrations was exceeded at two sites. Table 1 shows the number of days for each month during 1975 that the 8-hour and 1-hour average concentrations measured at the six monitoring sites exceeded the standards. The magnitude to which the 8-hour standard was exceeded is shown in Table 2.

The magnitude of the concentrations exceeding the NAAQS range from 10.4 mg/m^3 (9.1 ppm) to 44.3 mg/m^3 (38.9 ppm). The cumulative frequency distribution for the data shown in Table 2 is presented in Figure 2. This figure shows that the 50th percentile concentration is approximately 128 percent of the 8-hour standard or 13.1 mg/m^3 (11.5 ppm).

Discussions with the Department of Environmental Services officials indicated that the basic patterns of carbon monoxide concentrations recorded during 1976 at the six monitoring sites were quite similar to those for 1975, with respect to both frequency and magnitude of violations of the

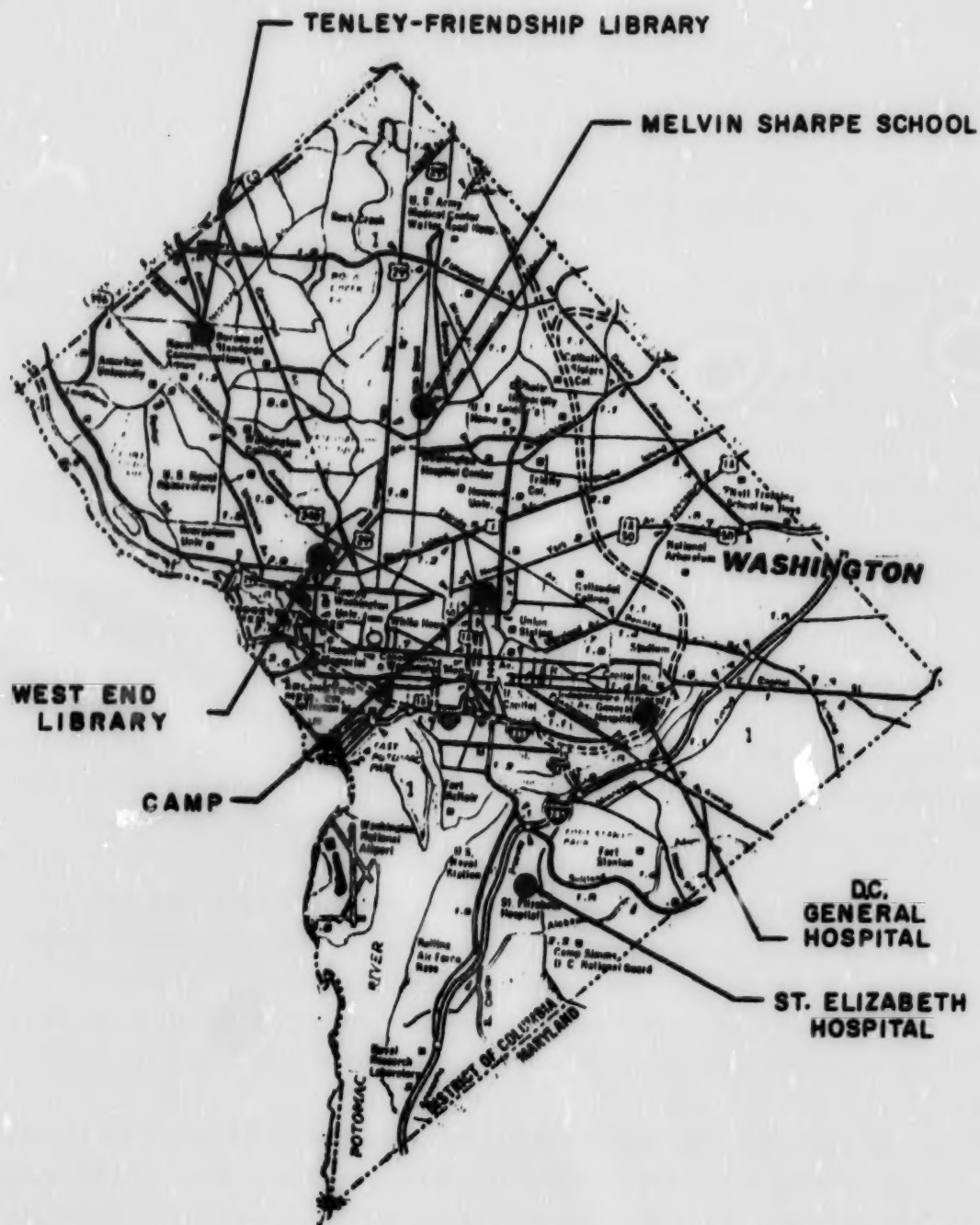


Figure 1. Carbon monoxide monitoring sites, Washington, D.C.

Table 1. NUMBER OF DAYS DURING EACH MONTH OF 1975 WHEN THE 8-HOUR AND 1-HOUR STANDARDS FOR CO WERE EXCEEDED AT SIX LOCATIONS IN WASHINGTON D. C.

Location	Standard	Number of days whose NAAQS was exceeded											
		Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Tenley-Friendship	8-hour	a	2	0	1	2	a	0	a	a	a	7	3
	1-hour	a	0	0	0	0	a	0	a	a	a	0	0
Melvin Sharpe	8-hour	3	6	3	1	2	1	3	0	0	2	5	5
	1-hour	0	1	0	0	0	0	0	0	0	0	0	0
D.C. General	8-hour	2	2	0	0	2	0	a	a	0	0	2	3
	1-hour	0	0	0	0	0	0	a	a	0	0	0	0
St. Elizabeth's	8-hour	a	a	a	a	a	a	a	a	a	0	3	2
	1-hour	0	0	0	0	0	0	0	0	0	0	0	0
CAMP	8-hour	1	1	1	0	0	0	0	1	a	a	a	10
	1-hour	0	0	0	0	0	0	0	0	a	a	a	2
West End Library	8-hour	a	a	a	2	0	a	a	a	a	a	3	a
	1-hour	a	a	a	0	0	a	a	a	a	a	0	a

^a Incomplete data (fewer than 15 days reported).

Source: Reference 2.

Table 2. EIGHT-HOUR CONCENTRATIONS EXCEEDING THE NAAQS BY MONTH AND DAY FOR SIX LOCATIONS IN WASHINGTON, D.C.

Location	Date	Maximum concentration	
		mg/m ³	(ppm)
Tenley-Friendship	5 Feb. 75	12.7	(11.1)
	24 Feb. 75	15.7	(13.8)
	28 Apr. 75	12.1	(10.6)
	3 May 75	11.7	(10.3)
	6 May 75	12.9	(11.3)
	11 Nov. 75	10.7	(9.4)
	12 Nov. 75	16.3	(14.3)
	15 Nov. 75	12.1	(10.6)
	17 Nov. 75	11.2	(9.8)
	24 Nov. 75	14.3	(12.5)
	25 Nov. 75	15.2	(13.3)
	26 Nov. 75	14.0	(12.3)
	1 Dec. 75	10.8	(9.5)
	4 Dec. 75	10.4	(9.1)
	26 Dec. 75	12.3	(10.8)
Malvin Sharpe	5 Jan. 75	10.4	(9.1)
	7 Jan. 75	19.8	(17.4)
	24 Jan. 75	15.8	(13.9)
	14 Feb. 75	12.9	(11.3)
	15 Feb. 75	18.9	(16.6)
	17 Feb. 75	13.2	(11.6)
	21 Feb. 75	10.6	(9.3)
	22 Feb. 75	30.7	(26.9)
	25 Feb. 75	15.8	(13.9)
	6 Mar. 75	21.7	(19.0)
	24 Mar. 75	14.4	(12.6)
	25 Mar. 75	12.8	(11.2)
	2 Apr. 75	11.2	(9.8)
	17 May 75	11.9	(10.4)
	29 May 75	10.8	(9.5)
	28 Jun. 75	10.6	(9.3)
	5 Jul. 75	10.9	(9.6)
	30 Jul. 75	11.8	(10.4)
	31 Jul. 75	10.6	(9.3)
	7 Oct. 75	10.9	(9.6)
	13 Oct. 75	12.9	(11.3)
	16 Nov. 75	14.9	(13.1)
	17 Nov. 75	14.9	(13.1)
	18 Nov. 75	17.4	(15.3)
	19 Nov. 75	17.7	(15.5)
	25 Nov. 75	12.1	(10.6)

Table 2 (continued). EIGHT-HOUR CONCENTRATIONS EXCEEDING THE NAAQS BY MONTH AND DAY FOR SIX LOCATIONS IN WASHINGTON, D.C.

Location	Date	Maximum concentration	
		mg/m ³	(ppm)
Melvin Sharpe (continued)	2 Dec. 75	16.3	(14.3)
	5 Dec. 75	18.2	(16.0)
	6 Dec. 75	14.0	(12.3)
	12 Dec. 75	20.5	(18.0)
	14 Dec. 75	22.9	(20.1)
D.C. General	7 Jan. 75	14.7	(12.9)
	24 Jan. 75	11.6	(10.2)
	15 Feb. 75	14.6	(12.8)
	22 Feb. 75	12.6	(11.1)
	16 May 75	13.1	(11.5)
	17 May 75	15.8	(13.9)
	17 Dec. 75	12.0	(10.5)
	18 Dec. 75	11.8	(10.4)
St. Elizabeth's	5 Nov. 75	14.7	(12.9)
	8 Nov. 75	15.3	(13.4)
	24 Nov. 75	10.4	(9.1)
	5 Dec. 75	12.9	(11.3)
	17 Dec. 75	10.9	(9.6)
CAMP	24 Jan. 75	13.3	(11.7)
	15 Feb. 75	11.6	(10.2)
	24 Mar. 75	15.4	(13.5)
	26 Aug. 75	17.4	(15.3)
	4 Dec. 75	12.5	(11.0)
	5 Dec. 75	44.3	(38.9)
	6 Dec. 75	27.8	(24.4)
	8 Dec. 75	13.3	(11.7)
	9 Dec. 75	13.7	(12.0)
	11 Dec. 75	17.6	(15.4)
	12 Dec. 75	14.9	(13.1)
	13 Dec. 75	16.0	(14.0)
	17 Dec. 75	11.5	(10.1)
	31 Dec. 75	13.1	(11.5)
	1 Apr. 75	12.1	(10.6)
	2 Apr. 75	13.4	(11.8)
	12 Nov. 75	11.3	(9.9)
	13 Nov. 75	15.2	(13.3)
	18 Nov. 75	10.9	(9.6)

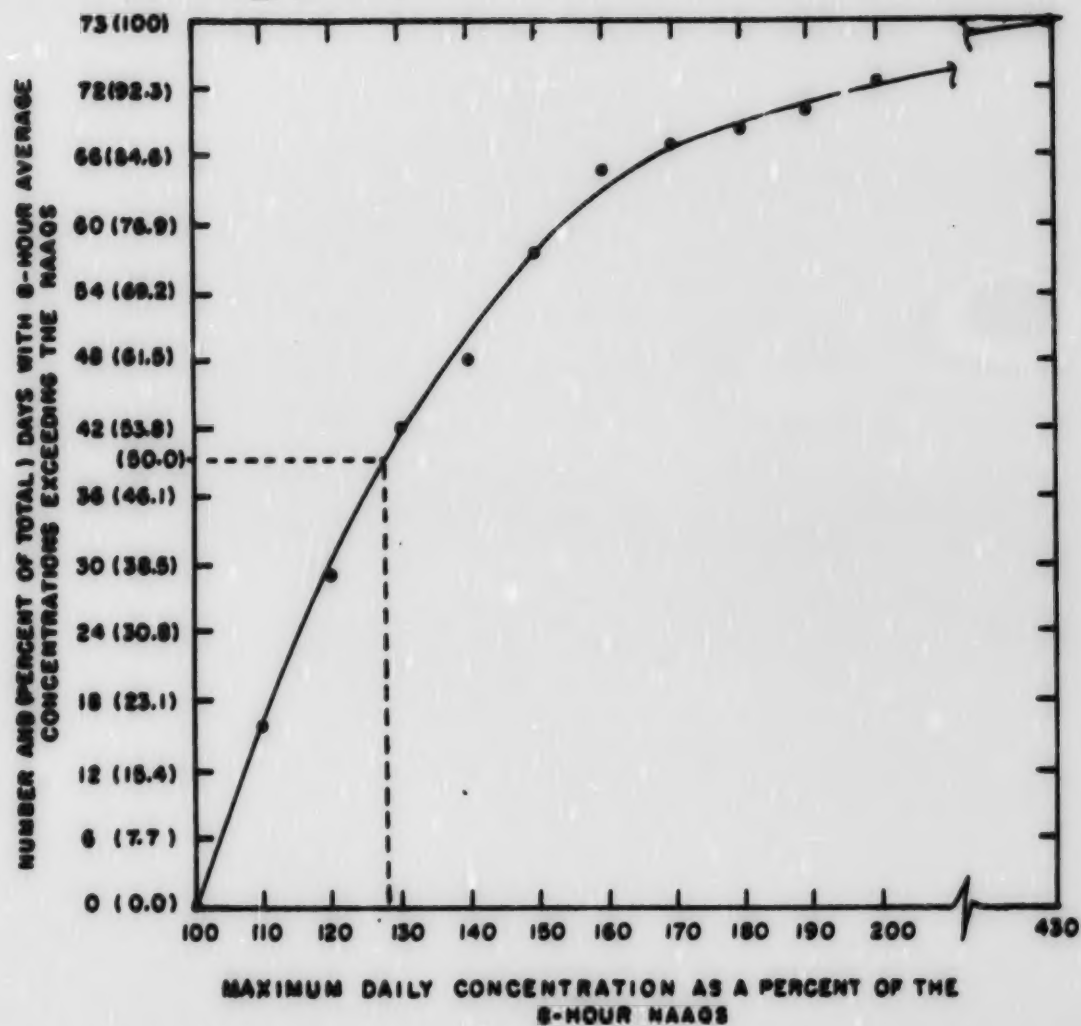


Figure 2. Cumulative frequency distribution of the number of days with 8-hour average CO measurements exceeding the NAAQS, as a function of the concentrations measured

8-hour NAAQS. One exception, however, was that the number of days when the 8-hour NAAQS was exceeded at the Melvin Sharpe School monitor decreased from 31 in 1975 to 6 in 1976. Also, the 1-hour NAAQS was not exceeded at the Melvin Sharpe School during 1976.

The data shown in Tables 1 and 2 indicate directly that the NAAQS for carbon monoxide is being routinely exceeded at at least six locations within the city. The implication, however, is that carbon monoxide problems* may exist in many other areas of the city and these problems may be much more severe than those indicated at the six monitoring sites. This is based on (1) the generally accepted premise that the carbon monoxide concentration occurring at any point is a function of emissions strength, spacial separation of the emission source and the point of interest, and a factor that reflects the dispersion characteristics (e.g., windspeed and direction, atmospheric stability, etc.) once the carbon monoxide has been emitted to the ambient atmosphere; and (2) the actual locations of the six monitors with respect to both the overall street system and the individual monitoring sites. The highest concentrations within a city are expected to occur at locations that typically experience the highest traffic volumes and levels of congestion. In Washington, D.C., these areas include the entire downtown, arterial corridors such as along the Potomac River, Connecticut Avenue, Massachusetts Avenue, etc.; and in the vicinity of very active generators such as National Airport. Monitoring stations are not operated within these areas where the greatest quantities of emission are likely to occur.

Also, a review of each monitoring site indicates that the sampling devices are generally not located at the point where the highest concentrations (to which the public might be exposed) are likely to occur. For instance, probes are often located on rooftops at heights of 10 to 15 meters or more above the sidewalk elevation. Also, probes are often

*Problems in this context meaning that ambient concentrations exceed the NAAQS.

set back from the sidewalk (or other reasonable receptor site) at distances of 10 to 15 meters. This implies that even at the individual monitoring sites, maximum concentrations are not necessarily being monitored.

A conclusion is that the apparent carbon monoxide problem in Washington, D.C. cannot be characterized adequately using only data derived from the air quality monitoring stations currently being operated. To adequately delineate the problem citywide, an analysis is required to characterize individual locations (i.e., hot spots) where street-level concentrations of carbon monoxide may be exceeding the NAAQS on a routine basis; the purpose of this report, then, is to demonstrate how the Hot Spot Guidelines can be used to analyze this problem.

SECTION III

STUDY METHODOLOGY

THE CO HOT SPOT GUIDELINES

Concept

In the analysis of carbon monoxide problems on an areawide scale there is a need for a method other than monitoring that will identify specific locations that are potential hot spots, and that will provide dimension to this potential. Several computer models provide this capability; however, computer models are generally expensive and complicated to run, therefore it usually is inefficient to use this approach in the first phases of an areawide analysis. The need for a somewhat less sophisticated technique for performing initial studies of areawide CO problems resulted in the development of the Hot Spot Guidelines (see Reference 1, Chapter 1).

The Hot Spot Guidelines provide the means for analyzing areawide CO problems at three levels of detail. The first level, preliminary screening, provides a manual technique for identifying specific locations that have hot spot potential, using very general data that are routinely available at the local level. The second level of analysis provides an estimate of the maximum concentration for a location, again using a manual technique, but based on data that are much more site-specific than are used for the preliminary screening. The third level involves computer modeling using very detailed data that reflect specific traffic operating characteristics and meteorological conditions; all three procedures are based largely on Supplement No. 5 to AP-42. Each of these three levels of analysis is discussed in the following paragraphs.

CO Screening

The implied relationship between air quality and traffic operating characteristics actually is a relationship between air quality and emissions intensity. In the vicinity of highways emission intensity depends on parameters such as traffic volume, emission characteristics of the vehicle fleet, quantitative and qualitative operating characteristics (capacity and level of service) of the roadway or intersection, and the actual orientation from the emissions source (e.g., the distance from and height above the traffic lane). Added to the air quality effects of the emissions intensity at any location is the background concentration which results from extra- and intraurban diffusion of the pollutant (carbon monoxide), and the prevailing meteorological conditions (macroscale and microscale).

Of the parameters outlined above, capacity and volume characteristics will vary most significantly among locations, while it can be assumed that the other parameters are constant throughout an area. Therefore, the CO screening process is based on an air quality-emissions intensity relationship where emissions intensity is the independent variable. Also, emissions intensity is considered to be a function of two variables - volume demand and facility capacity - and a constant set of factors to account for the vehicle-fleet emissions characteristics, orientation and distance from the source, background concentrations, and prevailing meteorology.

In the hot spot screening procedures, a distinction is made between factors that are site-specific and those that do not vary significantly from one site to another. The highly site-specific elements, such as traffic volume, speed, roadway capacity, and the distance separating the roadway and the assumed receptor location, are determined separately for each location being analyzed and are treated as variables in the computations. Other factors that do not change significantly within a region or state are determined just once for each screening program. These include

composite emission factors. Only expected worst-case meteorological conditions are considered in conducting the screening analysis.

A series of nomographs is presented in the Hot Spot Guidelines that depict the relationship between certain traffic factors and CO concentrations. More specifically, the screening nomographs show "critical volumes" (that is, the maximum traffic volume below which violations to the air quality standards for CO are not expected) for numerous roadway configurations within each of three general categories, including signalized intersections, free-flowing sections of expressways and arterials, and STOP sign-controlled intersections. The screening nomographs that were used in the analysis are reproduced in Appendix A for reference.

The process outlined in the Hot Spot Guidelines for conducting an areawide screening analysis begins with compiling the necessary traffic data. The general types of data required include areawide volume data in the form of a traffic flow or volume map, an inventory of signalized and STOP signs controlled intersections, and a physical inventory of the street network that identifies the number of lanes used and the type of operation (one-way or two-way).

The Hot Spot Guidelines recommends that all signalized intersections within the study area be analyzed for hot spot potential. Criteria are also presented in the Hot Spot Guidelines for selecting midblock or free-flowing locations, and STOP sign-controlled intersections for screening. The reader is referred to the Hot Spot Guidelines for a detailed description of the screening procedure; the procedure is outlined here, however, in the flow diagram presented in Figure 3.

Hot Spot Verification

The verification process is a follow-up to the initial screening of an area. The intent is to perform a more detailed evaluation of the hot spot potential of a street section or intersection using a technique that

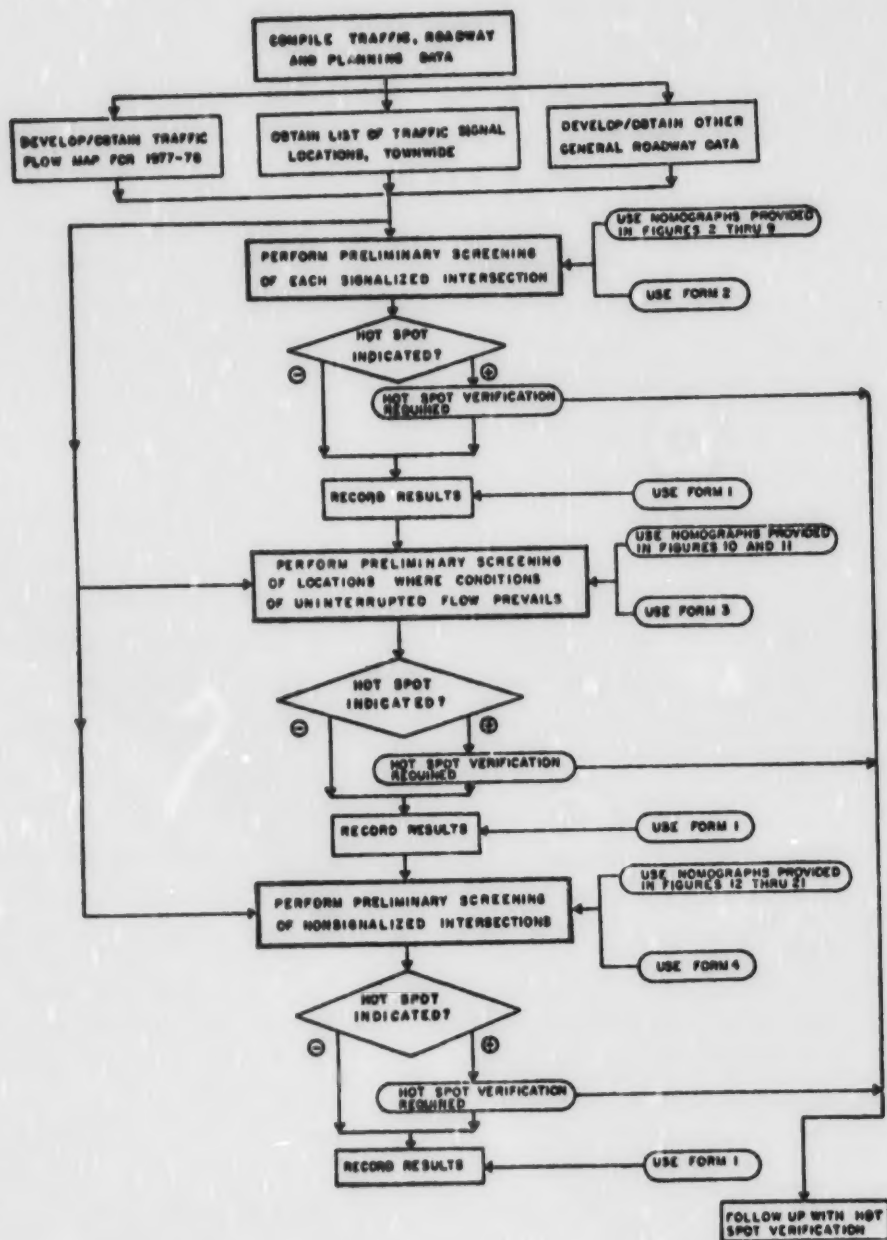


Figure 3. Process flow diagram for the screening of carbon monoxide hot spots

allows input of parameters specific to that location rather than assumed parameters. The initial screening process focuses on identifying potential hot spot locations anywhere within a city (thereby requiring a very general approach); the verification process analyzes specific locations, and a more detailed analysis of each location is feasible.

Conceptually, the technique involved is identical to that used for preliminary screening. It assumes an explicit relationship between air quality, traffic operating characteristics, and physical characteristics of an intersection, for particular meteorological conditions. Therefore, if both traffic and physical characteristics are determined, and a particular set of meteorological conditions assumed, estimates of the resulting air quality can be made. Again, these estimates are made using a series of curves that relate various traffic and roadway characteristics to resulting air quality.

The purpose of the verification process is to provide a quantitative estimate of the highest expected 1-hour and 8-hour average carbon monoxide in the vicinity of the roadway under analysis. Since a worst-case analysis is being performed, it is desirable to maximize the effects of traffic, meteorology, and receptor siting. Thus, the CO concentration estimate is made using peak hour traffic data, temperatures typical of cold winter days, and low wind speed (1 m/sec).

The verification process requires detailed data that are specific to the particular location being analyzed. The types of data required include:

- Physical data including roadway alignment, number of lanes, street widths, receptor location, etc.
- Traffic volume data including current peak-hour volume and statistics from which projections can be made.
- Speed data.
- Receptor orientation.
- Vehicle classification data.

- Traffic signal data.
- Estimates of the percentages of vehicles operating in the hot or cold mode, and
- Miscellaneous data regarding actions that will affect either traffic or travel within the study area, or the emission characteristics of the local vehicle fleet.

The reader is again referred to the Hot Spot Guidelines for a discussion of the details concerning the data required for hot spot verification.

Hot spot verification is conducted using the data elements mentioned above and a series of curves and tables presented in the Hot Spot Guidelines. The hot spot verification process will yield the expected worst-case carbon monoxide concentration in the vicinity of the roadway. The procedure used to analyze each location can be summarized as follows:

1. Specify the site-specific traffic and roadway parameters.
2. Determine the optimum receptor placement.
3. Determine the emission rates.
4. Apply emission correction factors to account for variability in calendar year, vehicle mix, temperature, altitude, and percent of cold operating vehicles.
5. Determine the normalized concentration contribution of the roadway(s) at the receptor site.
6. Apply the distance correction factors.
7. Apply the 8-hour averaging factor, if appropriate.
8. Add the background carbon monoxide concentration.

Basically, this procedure consists of solving the following equation for the expected peak carbon monoxide concentration for an 8-hour averaging period:

$$x_8 = C_8 C_E \left[C_{d_f} Q_f \left(\frac{x_u}{Q} \right)_f + C_{d_e} Q_e \left(\frac{x_u}{Q} \right)_e \right] / u + x_B \quad (1)$$

where

- x_8 = the estimated 8-hour average CO concentration at the receptor;
- C_8 = empirical conversion factor to change from a 1-hour averaging time to an 8-hour averaging time;
- C_E = emissions correction factor combining the effects of calendar year, vehicle-mix, altitude, temperature, proportion of cold-operating vehicles, and state (California or non-California);
- Q_f = the emission rate (g/m-sec) of carbon monoxide from freely flowing traffic;
- $(xu/Q)_f$ = the normalized concentration (m^{-1}) at the receptor resulting from free-flow emissions;
- Cd_f = distance correction factor for the concentration contribution from free flow emissions;
- Q_e = the excess emission rate from interrupted flow due to idling, acceleration, and deceleration (g/m-sec);
- $(xu/Q)_e$ = normalized concentration due to excess emissions from interrupted flow (m^{-1});
- Cd_e = distance correction factor for the concentration contribution from excess emissions from interrupted flow;
- u = windspeed (m/sec); and
- x_8 = background concentration.

If the receptor is near a roadway with interrupted flow (signalized or signed intersections), then the entire equation must be solved. If the receptor is located near a roadway where only uninterrupted flow conditions occur, then only the free flow portion of the equation (subscript "f" variables) must be solved and the excess emission terms (subscript "e" variables) within the brackets may be dropped. Again, the Hot Spot Guidelines provide detailed instructions for solving for x_8 and also provide tables and curves necessary to derive each term of the equation.

Hot Spot Modeling

The third phase of hot spot analysis involves computer simulation of traffic flow and air quality.

The model used for the simulation is referred to as the Intersection Midblock Model. The primary components of this model are the Modal Analysis Model,³ a traffic flow model, and the HIWAY Model.⁴ In its present form, the Intersection Midblock Model can accommodate multiple analyses of individual intersections or street sections. The model characterizes an intersection in terms of the links approaching and leaving the intersection, the type of intersection control (demand actuated, fixed time or two-way stop), cycle time, green time, and capacity for each phase and approach. The model also has the capability of treating free flow traffic conditions and the variation of traffic volumes on an hourly basis. Link input parameters include coordinates of the starting and endpoint, number of lanes, fraction of volume assigned to each lane, emission height, link width, volume and cruise speed. For those links approaching an intersection the deceleration into and the acceleration out of the intersection are also specified for the calculation of acceleration/deceleration emissions in the traffic queue. Receptor input data include the receptor coordinates and height above ground, and for those receptors located along street canyons, the direction of the street from north, receptor street width, building height and side of the street on which the receptor is located.

As a first step in the calculation, emissions rates for deceleration (g/vehicle), acceleration (g/vehicle), cruising (g/vehicle/sec) and idling (g/vehicle/sec) are calculated for those links approaching intersections. Cruise emission rates are then calculated for those links not approaching an intersection. Intersection traffic calculations are then performed to compute queue lengths, cycle times and queue delays which are then used to determine line source excess emission rates (g/m/sec). For each physical link approaching an intersection two links are constructed within the model. The first is identical to the physical link with cruise emissions

assigned to the entire length. The second link has the same terminus as the physical links but has a length equal to the average queue length over which the emissions are distributed. These emission rates together with hourly meteorological data (windspeed, wind direction and atmospheric stability) are used by either the HIWAY Model or Street Canyon Model⁵ to calculate hourly carbon monoxide concentrations at selected receptor locations. The final determination as to whether the street canyon model will be used for a given hour is determined by a criterion that involves atmospheric stability, wind speed, street width and building height.

Application of the Hot Spot Guidelines

The first phase of the hot spot analysis involved areawide screening. The Hot Spot Guidelines indicate that the screening effort should include consideration of signalized intersections, midblock arterial and expressway locations, and selected nonsignalized intersections. For this project, however, it was decided that the screening process would consider signalized intersections only. This decision does not substantially reduce the effectiveness of the study in either demonstrating use of the Hot Spot Guidelines or delineating the potential CO problem in the District. Had the analysis included midblock sections of arterials and nonsignalized intersections, it is noted that all locations within each of these categories would not have been analyzed anyway. The screening procedures specify that only midblock sections and nonsignalized intersections that are clearly not influenced by the presence of a signalized intersection either upstream or downstream shall be analyzed.*

*The Hot Spot Guidelines suggest that signalized intersections can affect traffic within a distance of about a half mile, therefore only midblock sections of arterials and nonsignalized intersections that are greater than a half-mile from a signalized intersection should be analyzed. Further, the Guidelines state that the only expressway sections that need be considered are those where the daily volumes exceed 30,000 (for 4-lane highways), 40,000 (for 6-lane highways), or 50,000 for (8-lane highways) vehicles.

This specification eliminated many locations from consideration owing to the rather high density of signalized intersections within the District (there are over 1,100 signalized intersections within the approximately 70 square mile area of the District).

The second phase of the analysis, involving hot spot verification, was also limited. Ordinarily, verification would be conducted at every location identified in the preliminary screening as either having a hot spot potential or being a complex intersection or special case.* For the purposes of this study, verification was performed at 29 intersections. The two primary criteria used in selecting locations for verification were the desire to analyze several functionally-different types of locations in several types of setting and the need to maximize use of existing data.

The third phase of the analysis involved comparing the results of the modeling phase with monitor data. This was accomplished by modeling air quality at two monitoring sites and comparing the results with measured hourly concentrations for several days during 1974, 1975, and 1976.

The final phase of the study involved comparing long-term monitoring data with the results of the verification analysis. The primary constraint here was the lack of monitoring sites where the actual monitor was situated in a manner that approximated the assumed receptor location. In fact, only one monitoring site provided a reasonable approximation of the assumed receptor location, and this phase of the study involved the analysis of that location.

Summary

As the study methodology implies, the focus of the project was to provide a demonstration of the Hot Spot Guidelines as well as a first level analysis of potential CO problems in Washington, D.C. In this connection, it should not be inferred that the study provided a comprehensive analysis of CO problems in the District. The conduct and results of the study are described in the following section.

* Complex intersections are those with unusual geometry or signal cycles that include more than two phases; special cases are locations where the signal is operated manually or only during certain hours of the days.

SECTION IV

STUDY PROCEDURE AND RESULTS

INTRODUCTION

As indicated in the previous section, the study methodology consisted of four separate phases, viz:

- Hot spot screening
- Hot spot verification
- Hot spot modeling
- Comparison of verification procedure results with monitoring data

The purpose of this section is to describe the procedures and data used in conducting each of the four phases of the study as well as to present the results of each.

HOT SPOT SCREENING

Screening Procedure

The hot spot screening process involved the analysis of all signalized intersections in the District. The first step in the process was to compile a data base. In this connection, arrangements were made with the District of Columbia Department of Transportation, Bureau of Traffic Engineering and Operations to obtain several necessary data elements including (1) an areawide traffic volume map depicting 1975 average daily traffic (ADT) volumes for most streets in the District, (2) a street log that included block-by-block pavement widths for all streets in the District,

and (3) a traffic signal locations map. These data were assembled and reviewed, and any apparent inconsistencies, omissions, or other inadequacies were recorded so that appropriate action (i.e., field reconnaissance or additional data requests) could be taken to complete the data base.

A total of 1131 signalized intersections were identified from the data. These locations were analyzed for hot spot potential using the preliminary screening procedures described in the Hot Spot Guidelines. The analysis year represented in the screening is 1977. The traffic volume data, which reflected 1975 ADT, were adjusted to more closely reflect 1977 conditions by increasing link volumes by 8 percent and rounding to the nearest thousand.

The appropriate data for each intersection were entered on a worksheet, a portion of which is presented in Figure 4 below.

Part I Location: _____

Part II Congested Area? Yes: _____ No: _____

Part III Complete Intersection or Special Case? Yes: _____ No: _____ If yes, enter location on Initial Screening Summary Sheet and proceed to next intersection; if no, proceed with Part IV.

Part IV Analyze each leg separately on the form, below.

Leg under analysis			Cross-street data							
			Street: _____ Leg: _____				Street: _____ Leg: _____			
a	b	c	d	e	f	g	h	i	j	k
Designation	Adjusted ADT (1977-78)	Configuration	Adjusted ADT (1977-78)	Configuration	Figure/curve used	Hot spot indicated	Adjusted ADT (1977-78)	Configuration	Figure/curve used	Hot spot indicated

Figure 4. Sample section of the worksheet used in the preliminary screening of Washington, D.C.

The actual determination of whether or not a location had hot spot potential was based on the screening curves presented in the Hot Spot Guidelines (also, see Appendix A). Throughout this phase of the study each intersection was analyzed only to the point where it was shown that hot spot potential did or did not exist; in other words, if the first approach analyzed displayed hot spot potential, then no additional approaches were analyzed.

Several examples of completed worksheets are provided in Appendix B, and a detailed description of the actual application of the procedure is provided in Appendix D.

Screening Results

The results of the screening analysis are most meaningfully portrayed in summary form as presented in Table 3.

Table 3. SUMMARY OF PRELIMINARY HOT SPOT SCREENING IN WASHINGTON, D.C.

Status	Number of locations
• Identified as having hot spot potential	660
• Determined not to have hot spot potential	103
• Not analyzed-complex intersection or special case	270
• Not analyzed-insufficient data	98
Total number of locations	1,131

Obviously, the analysis indicates that a rather extensive potential exists for hot spot problems in the District. This conclusion is based not only on the 660 locations specifically identified as having hot spot potential, but also on the observation that many of the intersections included in the category of complex intersections are located along very high volume

arterials and the combination of high volumes and complex geometry undoubtedly results in hot spot potential. Similarly, the 98 intersections where sufficient data were not available are located along relatively lightly traveled streets and therefore many of these probably do not have hot spot potential.

To summarize the results of the screening analysis, it appears that the areal extent of the potential hot spot problem in Washington, D.C. is quite substantial. The locations identified as having hot spot potential are not confined to any particular section (e.g., the downtown area, around the tourist attractions, etc.) of the city. The single factor that contributes most significantly to hot spot potential is high volume demand; volume demand is uniformly high throughout the entire District.

A listing of all locations analyzed and the status regarding hot spot potential is included in Appendix C.

Level of Effort Expended

The screening effort involved several individual tasks of both a technical and administrative nature. The technical tasks focused on data analysis and the actual screening, while the administrative functions included items such as developing work plans and supervising and checking the technical work performed. It would be expected that these types of tasks would be required regardless of the size of the area being screened or the depth of analysis. Specific tasks and the estimated effort expended for each are shown in Table 4.

Again, the tasks shown in Table 4 will generally be required for any area-wide screening analysis that utilizes the Hot Spot Guidelines. The actual effort can be expected to vary considerably, however, from city to city. Two factors are particularly important concerning the actual effort that would be required to conduct an areawide screening exercise - these include (1) the size of the area, or more specifically, the number of locations

that will be considered, and (2) the quality and quantity of available data. Fortunately, a very substantial quantity of high quality, relevant data was available from the District Department of Transportation, Bureau of Traffic Engineering and Operations, therefore relatively little effort was required to compile an adequate data base.

Table 4. SUMMARY OF EFFORT EXPENDED IN PERFORMING HOT SPOT SCREENING IN WASHINGTON, D.C.

Task	Type	Estimated man-hours expended
• Develop work plan	Administrative and technical	16
• Identify and contact data sources	Administrative, some technical	8
• Review and assemble data	Technical	16
• Conduct screening exercise	Technical	120
• Summarize results of screening exercise	Technical	24
• Supervise and check technical effort	Administrative	16
Total estimated man-hours		200

It is of interest to note that the actual analysis time for each intersection was about 5 minutes; this includes the time required to locate the intersection on the traffic volume map, identify the appropriate volumes, adjust the volumes, enter the data on the worksheet, determine the setting (congested or noncongested area) and types of approaches (e.g., 4-lane, 2-way), assess whether or not the intersection should be considered a complex intersection, and finally select and use the appropriate nomograph. Also, it is of interest to note that most of the technical work can be accomplished by individuals who have only limited exposure to traffic engineering practice; the Guidelines were, in fact, designed for use by subprofessional skill levels.

HOT SPOT VERIFICATION

Verification Procedure

Ordinarily, the verification procedure would be applied to all locations identified in the screening process as either having hot spot potential or being complex intersections or special cases. Had this procedure been followed here, the verification process would have been applied to about 950 separate intersections — this clearly was beyond the scope of this project. Instead, it was established that the analysis of 29 locations would provide a reasonably good demonstration of the procedure and at the same time be within the scope of the project.

As indicated previously, the criteria used in selecting study locations focused on the desire to (1) consider several functionally different types of locations situated in different urban settings, and (2) maximize the use of existing data. In this connection liaison was again established with the District Department of Transportation, Bureau of Traffic Engineering and Operations to identify locations where current data would be available for use in the analysis. Owing to the rather extensive data base maintained by the Bureau, it was possible to identify at least 29 locations that met both criteria.

For each location, the Bureau provided the following data elements:

1. 10-hour intersection turning movement counts including pedestrian crossing data, taken during 1975 and 1976.
2. Traffic signal data including phasing and timing diagrams.
3. Intersection layout drawing showing lane widths and use (one-way or two-way) and intersection geometry.

Field reconnaissance was required, however, to identify any unusual features associated with each location that would not be apparent from the abovementioned data elements. Also, field reconnaissance was required to identify "reasonable receptor" locations within each intersection as well.

Data were not available regarding the vehicle-type mix specific to each location; instead, a standard vehicle mix was assumed that included 88 percent light-duty vehicles, 8 percent light-duty trucks, 3 percent heavy-duty, gasoline-powered vehicles, and 1 percent heavy-duty, diesel-powered vehicles. Further, it was assumed that 5 percent of the vehicles were operating in the cold mode, and 10 percent in the hot transient mode. Correction factors for cold mode and hot transient vehicles were computed for both catalyst- and noncatalyst-equipped light-duty vehicles and light-duty trucks, using an assumed ambient temperature of 30°F.

The data described above were entered on the standard worksheet provided in the Hot Spot Guidelines and the maximum 8-hour average CO concentration computed using the procedures, curves, and tables also presented in the Guidelines. Appendix D provides a detailed description of the application of the verification procedure in the analysis of CO concentrations; Appendix E provides examples of completed verification worksheets for several intersections.

Results of the Verification Analysis

The verification process serves to quantify the hot spot potential at a location in terms of an estimated "worst case" concentration. These worst-case concentrations computed for the 29 study locations are presented in Table 5, below. As can be seen, all 29 locations appear to have the potential to exceed the 8-hour NAAQS of 10 mg/m³ (9.0 ppm) while 12 apparently have the potential to exceed the 1-hour standard of 40 mg/m³ (35.0 ppm).

The relative hot spot potential among the 29 locations can be seen in Figure 5 and Figure 6, which provide the grouped frequency distribution of the maximum 8-hour and maximum 1-hour average concentrations, respectively.

Table 5. RESULTS OF THE HOT SPOT VERIFICATION ANALYSIS AT 29 LOCATIONS IN WASHINGTON, D.C.

Location	Preliminary screening results			Maximum expected concentration, $\mu\text{g}/\text{m}^3$	
	Has hot spot potential	Complex inter. or special case	Insufficient data	1-hour average	8-hour average
1. Alabama Avenue @ Branch St.	X			50.1	35.1
2. E Street @ 7th Street NW	X			26.6	18.6
3. E Street @ 4th Street NW	X			20.2	14.2
4. G Street @ 14th Street NW	X			46.7	32.7
5. L Street @ 20th Street NW	X			27.4	19.1
6. Independence Avenue @ 6th Street NW			X	38.0	26.6
7. M.L. King Avenue @ Goodhope Road SE	X			34.7	24.3
8. M Street @ Whitehurst Parkway SW	X			43.8	30.7
9. L Street @ 9th Street NW	X			37.4	26.1
10. Rhode Island Avenue @ South Dakota Avenue NE	X			49.7	34.8
11. Monroe Street @ 12th Street NE	X			25.7	18.0
12. G Street @ 10th Street NW	X			20.6	14.4
13. Wisconsin Avenue @ Harrison Street NW	X			30.1	21.1
14. Georgia Avenue @ V Street NW	X			21.7	15.2
15. Massachusetts Avenue @ Wisconsin Avenue NW				32.3	26.6
16. 16th Street @ Kalmit Road NW	X			57.5	40.2
17. Pennsylvania Avenue @ 13th Street NW		X		63.2	44.3
18. F Street @ 13th Street NW	X			32.2	22.5
19. Nebraska Avenue @ Reno Road NW	X			47.2	33.1
20. Wisconsin Avenue @ N Street NW	X			21.1	14.8
21. Nebraska Avenue @ Van Ness Street NW	X			38.6	27.0
22. Rhode Island Avenue @ Florida Avenue NE		X		61.1	42.8
23. K Street @ Connecticut Avenue NW	X			54.1	37.9
24. L Street @ 6th Street		X		36.9	25.8
25. Pennsylvania Avenue @ 3rd Street NW	X			63.4	44.4
26. Wisconsin Avenue @ P Street NW	X			27.9	19.6
27. Florida Avenue @ 16th Street NW	X			29.1	20.4
28. Maryland Avenue @ 3rd Street SW		X		49.8	34.8
29. Wisconsin Avenue @ Albemarle Street NW	X			36.8	25.7

*Concentrations indicated represent the maximum expected at the closest reasonable receptor (usually the centerline of an adjacent sidewalk).

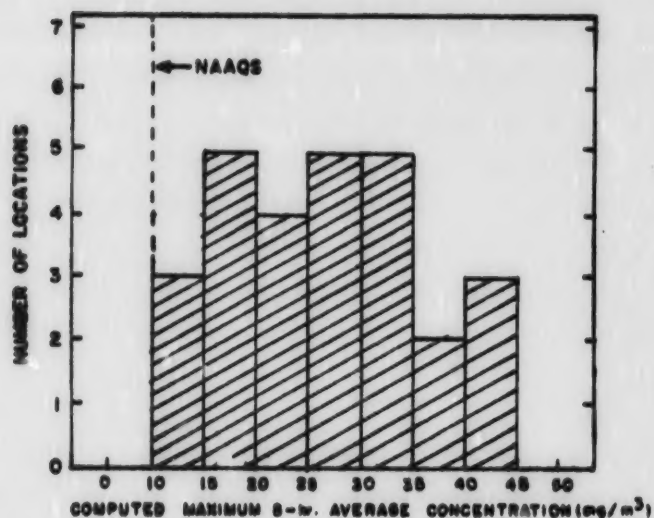


Figure 5. Grouped frequency distribution of maximum 8-hour average CO concentrations for 29 signalized intersections in Washington, D.C.

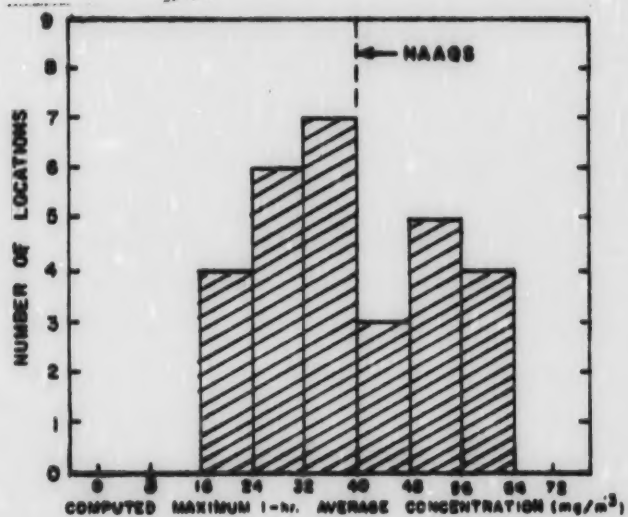


Figure 6. Grouped frequency distribution of maximum 1-hour average CO concentrations for 29 signalized intersections in Washington, D.C.

Care must be exercised in interpreting the results of the verification analysis. It is emphasized that the computations are based on worst case meteorological conditions, therefore the concentrations derived from the analysis are obviously higher than normal. An important aspect of assessing air quality problems concerns the frequency distribution of concentrations in excess of the various standards. In fact, the relative severity of an air quality problem cannot accurately be defined without both an indication of the frequency that the appropriate standard is exceeded, and a quantitative measure of the magnitude of the concentrations above the standard.

Several techniques have been suggested for investigating the probable frequency distribution for locations where long-term monitoring has not been used. Generally, these techniques include the analysis of macro- and micro-meteorological patterns, which provide the basis for describing the air quality distributions. These techniques are relatively complicated and are generally beyond the scope of the hot spot verification process -- it is important to emphasize that the screening and verification processes concern hot spot potential. A discussion of the frequency distribution of the highest concentrations expected at any location is presented in the Hot Spot Guidelines.

Level of Effort

The verification analysis involved both technical and administrative tasks of the type that would be expected for any study using the procedure. Table 6 provides a summary of the general categories of tasks and the amount of effort expended on each.

It is again important to note that the effort did not include extensive field data collection, owing to the availability of sufficient data from the District Department of Transportation. Had data not been available, it is quite likely that at least an additional 100 man-hours would have been required to perform field studies.

Table 6. SUMMARY OF EFFORT EXPENDED ON PERFORMING HOT SPOT VERIFICATION AT 29 LOCATIONS IN WASHINGTON, D.C.

Task	Type	Estimated man-hours expended
• Develop work plan	Administrative and technical	16
• Obtain data (including field reconnaissance)	Administrative and technical	64
• Review and assemble data	Technical	16
• Conduct verification exercise	Technical	40
• Summarize results of verification exercise	Technical	8
• Supervise technical effort	Administrative	16
Total estimated man-hours		160

While the procedures for hot spot verification are still somewhat general, the level of expertise required in traffic engineering is substantially greater than that required for screening. Much of the technical work can be accomplished by a technician with some exposure to various traffic engineering concepts and principles, but the nature of the process suggests that it would be appropriate for a professional-level traffic or transportation engineer to have overall technical and administrative responsibility for the analysis.

HOT SPOT MODELING

Site Selection

Two locations with CO monitors were used to test the Intersection Midblock Model. Although neither monitor was suitably located to coincide with the

receptor location assumed in the Guidelines,* the necessary input data were available to permit a demonstration of the model at each site.

The first site used is in Fairfax County, Virginia, near the intersection of Lewinsville Road and Route 123. CO is measured near the roof of the monitoring trailer and windspeed and direction are also observed at the site. Traffic data and the accompanying meteorological and CO data were made available to GCA/Technology Division from a study conducted by Engineering-Science for the County of Fairfax.⁶ Calculations were carried out for two 1-hour periods, selected to correspond with the morning and afternoon peaks in traffic volume, on 20 days during 1974 and 1975. Figure 7 shows the location of the monitoring site and the principal nearby intersection used in the model calculations.

The second demonstration of the model was carried out using the Tenley Friendship Library site near the intersection of Wisconsin Avenue and Albemarle Street (see Figure 8). Initial calculations at this site showed the type of problems likely to be encountered when attempting to validate an intersection model using data from an existing monitor. In this case, the monitor is located to the rear of the roof of a 13-meter high building. Using a height of 13 meters in the model results in zero concentration predictions because, for the stable or neutral atmospheric conditions assumed, all of the CO generated near the intersection passes below the monitor. A more realistic, though crude, assumption for this configuration of intersection and building is to assume that the air is forced up and over the structure, and that the monitor is therefore effectively at source height. With this assumption, hourly measured and calculated CO concentrations for this site were compared for 2 consecutive days in June when the wind direction during the morning rush hour was northeasterly. Also, the sensitivity of the calculated concentrations to wind direction was tested

* The assumed receptor location is at the point where the maximum concentration is most likely to occur at a height of approximately 2 meters and along a line generally parallel to and offset from the edge of the roadway.

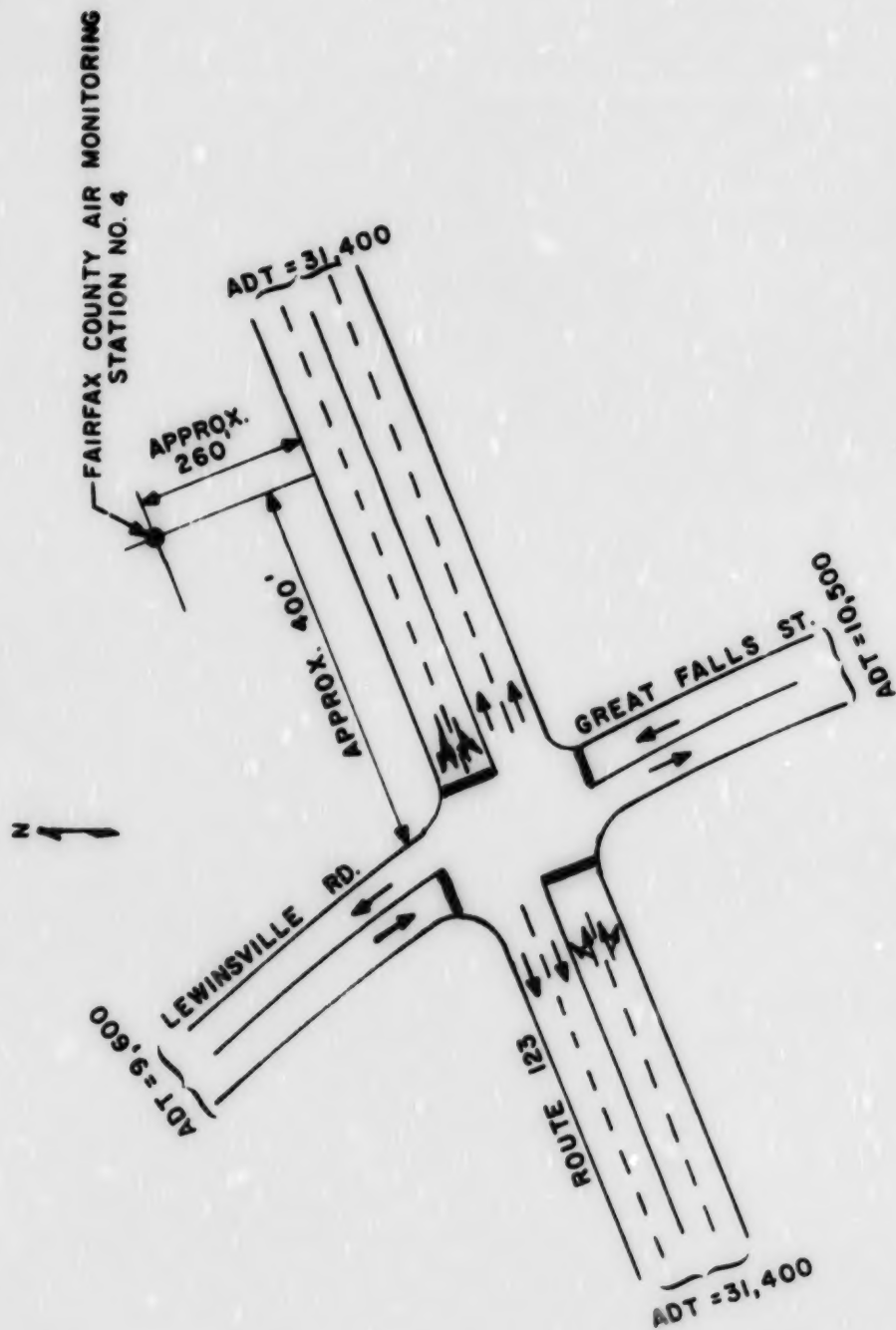


Figure 7. Location of Fairfax County Air Monitoring Station No. 4

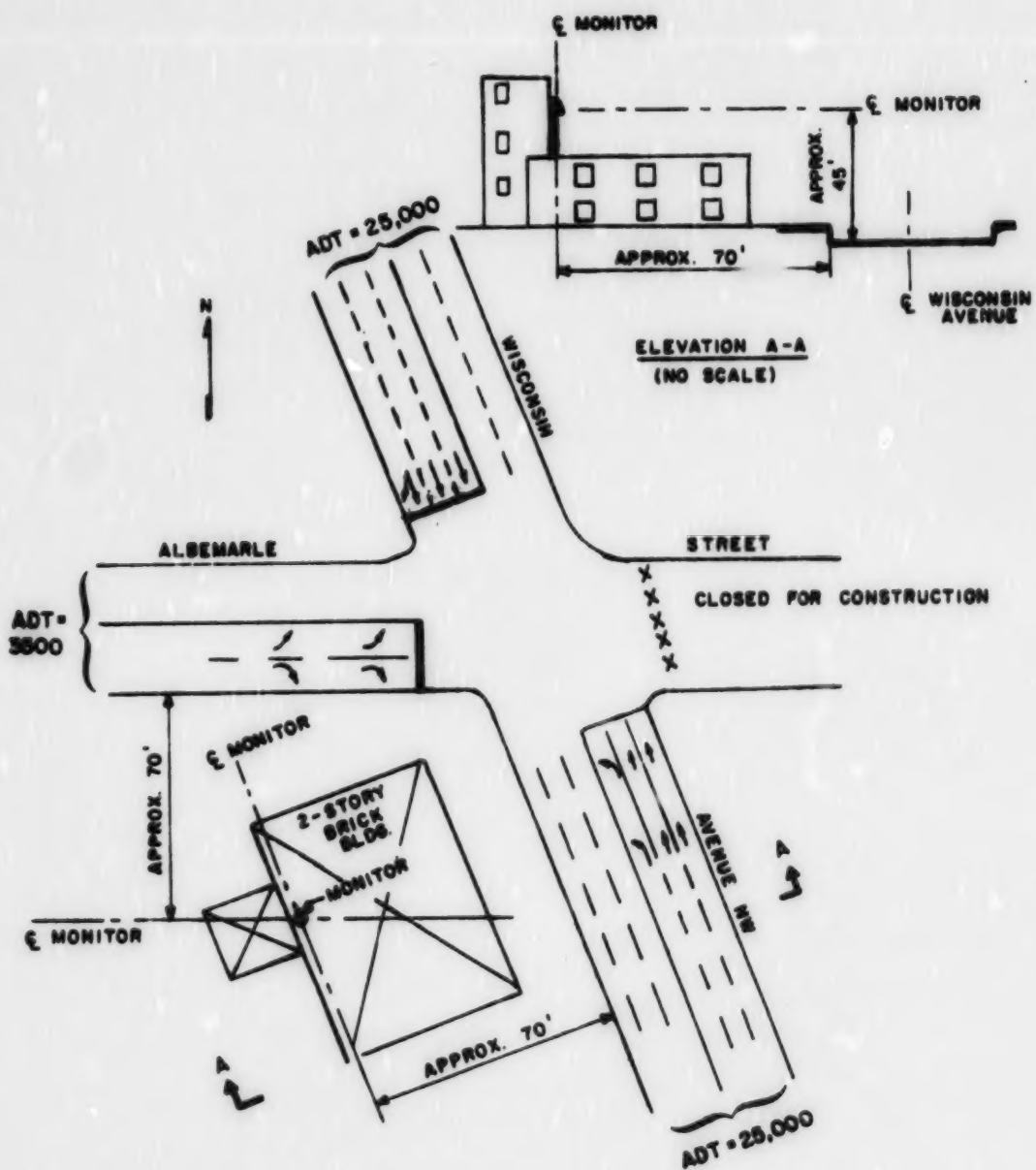


Figure 8. Site sketch - Wisconsin Avenue and Albemarle St., N.W., intersection

since the actual wind direction and windspeed at the intersection could well vary significantly from that interpolated from the 3-hourly observations at National Airport, and used in the model.

Results

In Table 7 the measured and calculated 1-hour CO concentrations at the Fairfax, Virginia site are presented along with the locally measured wind data, and the stability class for each hourly calculation. Examination of Table 7 shows that the model results, being based on the traffic flow at the intersection southwest of the monitor, are quite sensitive to wind direction. The contribution of the intersection to the monitor site becomes insignificant as the wind becomes westerly, while the observed values on two of these occasions equaled 4.6 mg/m^3 (4 ppm). During both these periods the windspeed was very light, and the wind direction probably was quite variable. Thus part of the 4.6 mg/m^3 (4 ppm) could have been contributed from the intersection as well as from other neighboring sources. Generally, the intersection model did not account for all of the observed CO, although at 0700 the agreement is close in four of the 16 cases, and the calculated value exceeds the observed in two cases. The average excess of observed over predicted at 0700 is 2.5 mg/m^3 (2.2 ppm), which is not an unreasonable background level for this time of day. At 1600, calculated concentrations are less than observed in all but one of the 19 cases, and the average difference between observed and predicted concentration is 1.4 mg/m^3 (1.2 ppm). In a version of the Intersection Midblock Model currently under development, background estimates, if desired, will be provided on an hourly basis by use of the APRAC-1a Model. The addition of background estimates should result in closer agreement between calculated and observed values.

The measured and calculated 1-hour CO concentrations at the Tenley Friendship Library, the wind conditions as interpolated from the National Airport 3-hourly data, and the stability for the two 8-hour periods tested are given in Table 8. During both periods, the use of the model without provision for background levels results in serious underprediction. The

Table 7. COMPARISONS BY MEASURED AND CALCULATED
CO CONCENTRATIONS AT THE FAIRFAX
STATION NO. 4

Date	Start hour	Wind direction, degree	Wind- speed, m/s	Stability class	CO observed, mg/m ³	CO calculated, mg/m ³
7/3/74	07	240	1.1	3	6.7	0.4
	16	260	2.1	2	0.7	—
7/14/74	07				M ^a	M
	16	210	3.6	2	0.0	0.6
7/15/74	07	210	2.9	4	1.4	2.1
	16	250	1.1	2	1.4	0.1
7/18/74	07	190	2.2	4	1.4	1.2
	16	195	3.6	3	0.0	0.8
8/17/74	07				M	M
	16	240	1.6	3	2.0	0.3
8/29/74	07				M	M
	16	200	3.8	2	4.6	0.6
9/12/74	07	180	1.3	4	4.0	1.3
	16	180	2.2	3	2.0	0.9
9/13/74	07	270	0.7	3	4.6	—
	16	150	2.2	3	2.6	0.5
10/17/74	07	250	1.1	3	4.6	0.2
	16	210	2.2	3	2.6	1.9
10/22/74	07	180	0.4	3	13.2	6.7
	16	230	1.6	3	3.3	0.8
11/4/74	07	180	1.3	3	5.3	1.1
	16	210	4.9	4	4.6	1.2
11/18/74	07	225	0.5	3	4.6	7.2
	16	195	2.7	4	5.3	2.9
12/17/74	07	210	0.9	3	13.2	8.2
	16	270	1.1	4	1.4	—
12/19/74	07	165	1.3	4	2.6	2.4
	16	225	2.0	4	4.0	1.5
3/6/75	07	195	1.3	3	6.7	3.3
	16	270	3.8	3	0.0	—
3/15/75	07	210	0.9	3	10.6	5.2
	16	285	4.0	4	0.7	—
4/24/75	07	210	4.7	4	1.4	1.4
	16	190	2.7	4	3.3	1.5
6/6/75	07	200	2.0	4	2.4	2.3
	16	260	2.7	2	0.7	—
6/6/75	07	200	2.0	4	2.6	2.3
	16	260	2.7	2	0.7	—
6/12/75	07	180	3.4	4	1.4	0.5
	16				M	M
6/23/75	07				M	M
	16	200	2.9	2	1.4	1.0

^aM reflects missing data.

Table 8. COMPARISON OF MEASURED AND CALCULATED
CO CONCENTRATIONS AT THE TENLEY FRIEND-
SHIP LIBRARY

Date	Start hour	Wind direction, degree	Wind- speed, m/sec	Stability class	CO observed, mg/m ³	CO calculated, mg/m ³
6/3/76 Thursday	4	30	4.3	6	4.6	1.5
	5	33	4.5	4	5.7	1.0
	6	36	4.7	4	6.9	1.0
	7	40	4.9	4	8.0	2.0
	8	43	5.4	3	9.2	1.3
	9	46	6.0	3	10.3	0.6
	10	50	6.5	3	1.1	0.3
	11	53	6.3	3	1.1	0.3
6/4/76 Friday	4	40	3.2	6	6.9	1.0
	5	36	3.8	4	6.9	1.0
	6	33	4.3	4	8.0	1.4
	7	30	4.9	3	9.2	2.5
	8	36	5.0	3	8.0	1.8
	9	43	5.2	3	6.9	0.8
	10	50	5.4	3	6.9	0.4
	11	63	5.4	3	5.7	0.6

probability that the background levels were high on these two mornings is supported by the observations during the 0300 to 0400 period when the volume of traffic through the intersection is very low. Concentrations reported for this hour on the third and fourth, respectively, were 3.5 and 5.7 mg/m³. The sensitivity of predicted concentrations to wind direction is illustrated in Table 9. The assumptions used in making these calculations were: windspeed, 1 meter per second; stability, class 4; mixing height, 5000 meters; traffic volume, 9 percent of ADT; and receptor height, 1 meter.

Table 9. CALCULATED 1-HOUR CO CONCENTRATIONS AS A FUNCTION OF WIND DIRECTION

Wind direction, degree	Concentration, mg/m ³	Wind direction, degree	Concentration, mg/m ³
0	13.8	50	3.9
5	17.0	55	3.6
10	18.2	60	3.9
15	17.4	65	4.7
20	15.6	70	5.6
25	13.3	75	6.3
30	10.8	80	6.7
35	8.5	85	7.0
40	6.4	90	7.5
45	4.9		

VERIFICATION RESULTS VERSUS MONITORING DATA

Procedure

An ideal test of the verification process would be to compare the results obtained from it to a set of measured data, assuming that both the measured data and the verification results reflect conditions at a common point in time and space. Unfortunately, a valid comparison of this type is virtually impossible if existing monitoring locations are used as the source of the measured data. The root of the problem is that the monitoring stations and the verification procedure generally are not considering the same point in space since the verification process assumes that the receptor is located at the point of maximum concentration.

Notwithstanding the above-mentioned problems, comparisons were made between the maximum CO concentration computed for the intersection of Wisconsin Avenue at Albemarle Street NW, and data summaries from the permanent monitoring station located near that intersection. A sketch of the intersection showing the orientation of the monitor with respect to the roadways was presented previously as Figure 8. The intent of this comparison was strictly to determine whether or not the verification procedure would provide a conservative estimate of worst case air quality.

Data from the monitoring station were obtained for much of 1975 from the District of Columbia Department of Environmental Services. These data indicated that the maximum 1-hour and 8-hour average concentrations at the site were 34.5 mg/m^3 (30.0 ppm)* and 16.4 mg/m^3 (14.3 ppm),* respectively, while the verification process computed maximum 1-hour and 8-hour average concentrations of 39.0 mg/m^3 (33.9 ppm) and 27.4 mg/m^3 (23.8 ppm), respectively.

It is very difficult to draw any conclusions regarding the predicted versus the measured maximum concentration. Perhaps the only conclusion that would be appropriate is that monitoring data does not necessarily reflect the highest concentrations that can occur within an intersection under the most severe (with respect to air pollution) meteorological conditions.

* Occurring on 30 November and 13 November, respectively, at the Tenley-Friendship Library site.

REFERENCES

1. Guidelines for Identification and Evaluation of Localized Violations of Carbon Monoxide Standards. GCA/Technology Division, Bedford, Massachusetts. Prepared for U.S. Environmental Protection Agency, Research Triangle Park, N.C. Contract No. 68-02-1376.
2. Annual Report on the Quality of the Air in Washington, D.C. 1975. Government of the District of Columbia, Department of Environmental Services, Bureau of Air and Water Quality, Air Monitoring Division.
3. Kunselman, P., et al. Automobile Exhaust Emission Modal Analysis Model. U.S. Environmental Protection Agency. Report No. EPA-460/3-74-005. January 1974.
4. Zimmerman, J.R. and R.S. Thompson. User's Guide for HIWAY: A Highway Air Pollution Model. EPA Report No. EPA-650/4-74-008. February 1975.
5. Ludwig, F.L. and R. L. Mancuso. User's Manual for the APRAC-1a Urban Diffusion Model Computer Program. Prepared for the Division of Meteorology, U.S. Environmental Protection Agency, Under Contract No. CAPA-3-68(1-69), (NTIS PB 213091). Research Triangle Park, N.C. 27711. September 1972.
6. Fairfax Air Quality Model. Submitted to County of Fairfax, Office of Research and Statistics, Fairfax, Virginia by Engineering-Science, McLean, Virginia, in association with Howard Needles Tammen & Bergenkoff, Alexandria, Virginia. November 18, 1976.

APPENDIX A
SCREENING NOMOGRAPH

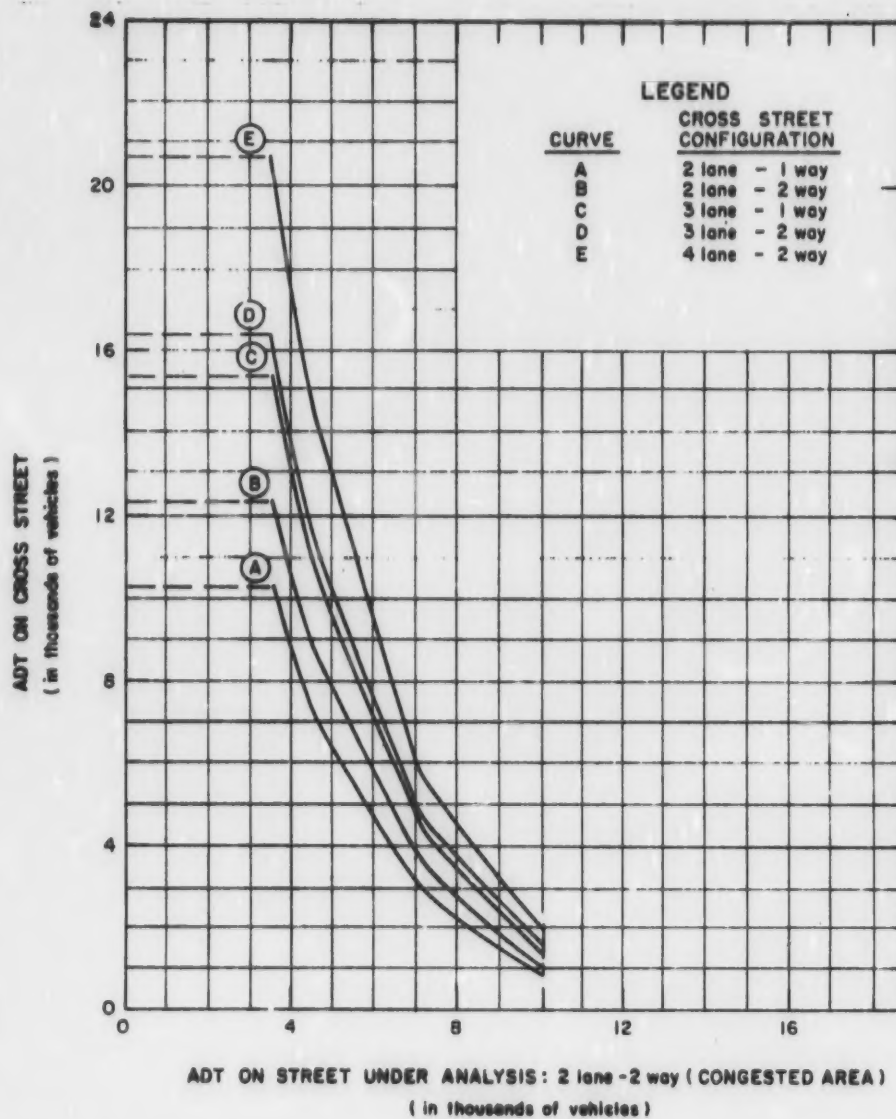


Figure A-1. Critical volumes at signalized intersections.
Analysis of a 2-lane 2-way street in a congested area

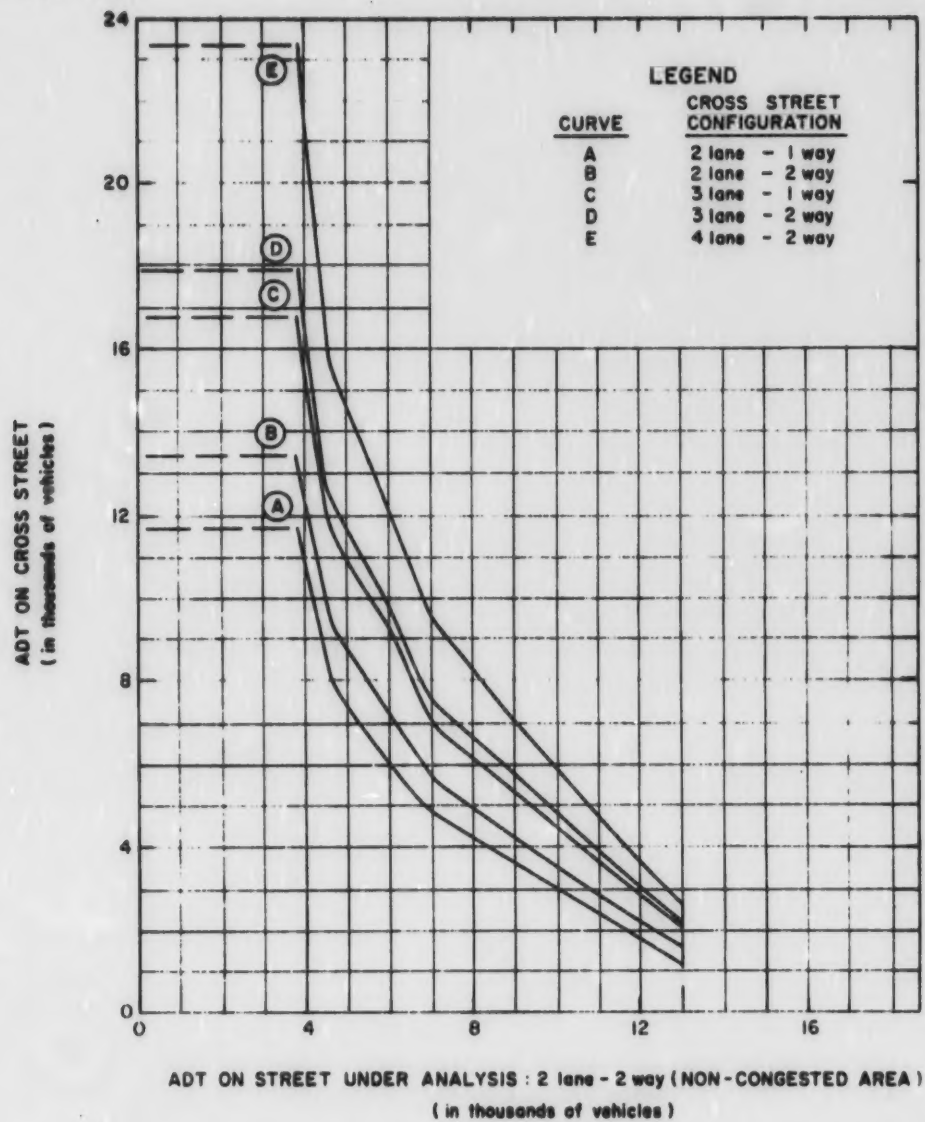


Figure A-2. Critical volumes at signalized intersections. Analysis of a 2-lane 2-way street in a non-congested area

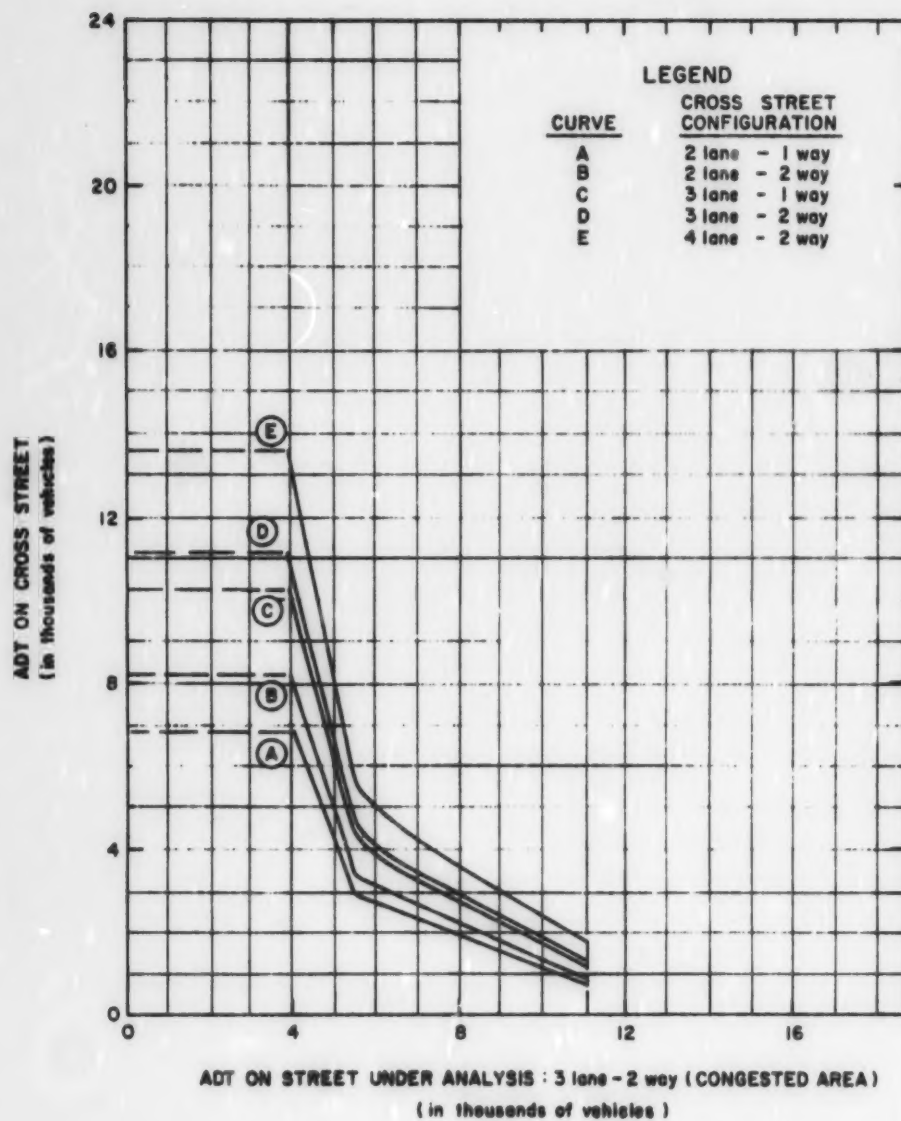


Figure A-3. Critical volumes at signalized intersections. Analysis of a 3-lane 2-way street in a congested area

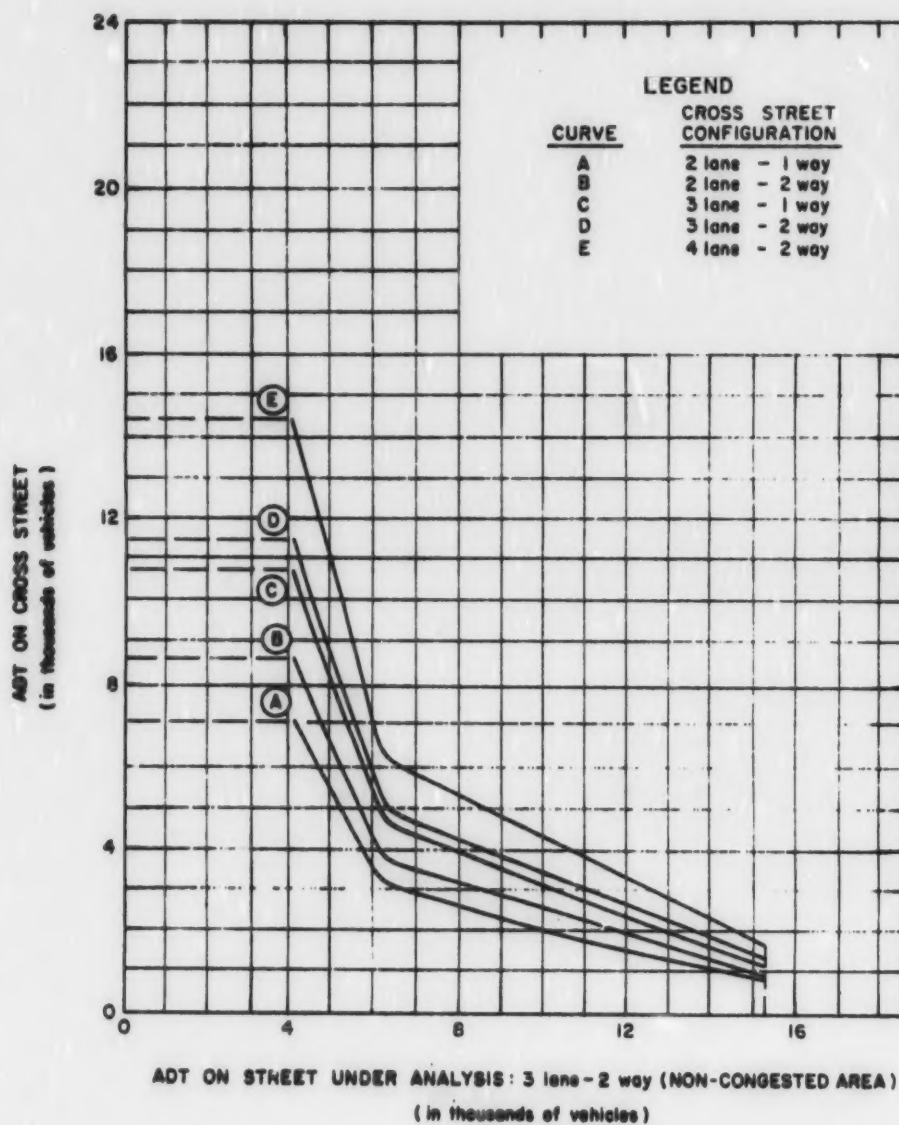


Figure A-4. Critical volumes at signalized intersections. Analysis of a 3-lane 2-way street in a non-congested area

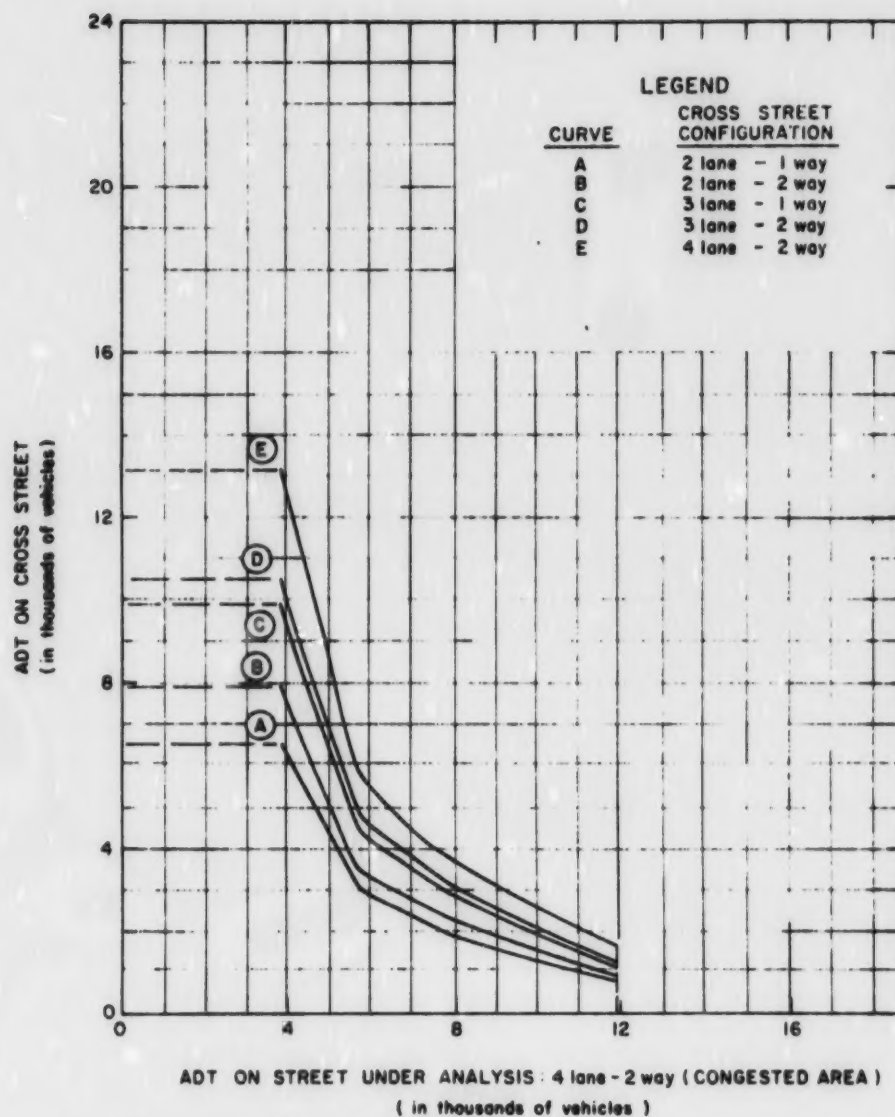


Figure A-5. Critical volumes at signalized intersections. Analysis of a 4-lane 2-way street in a congested area

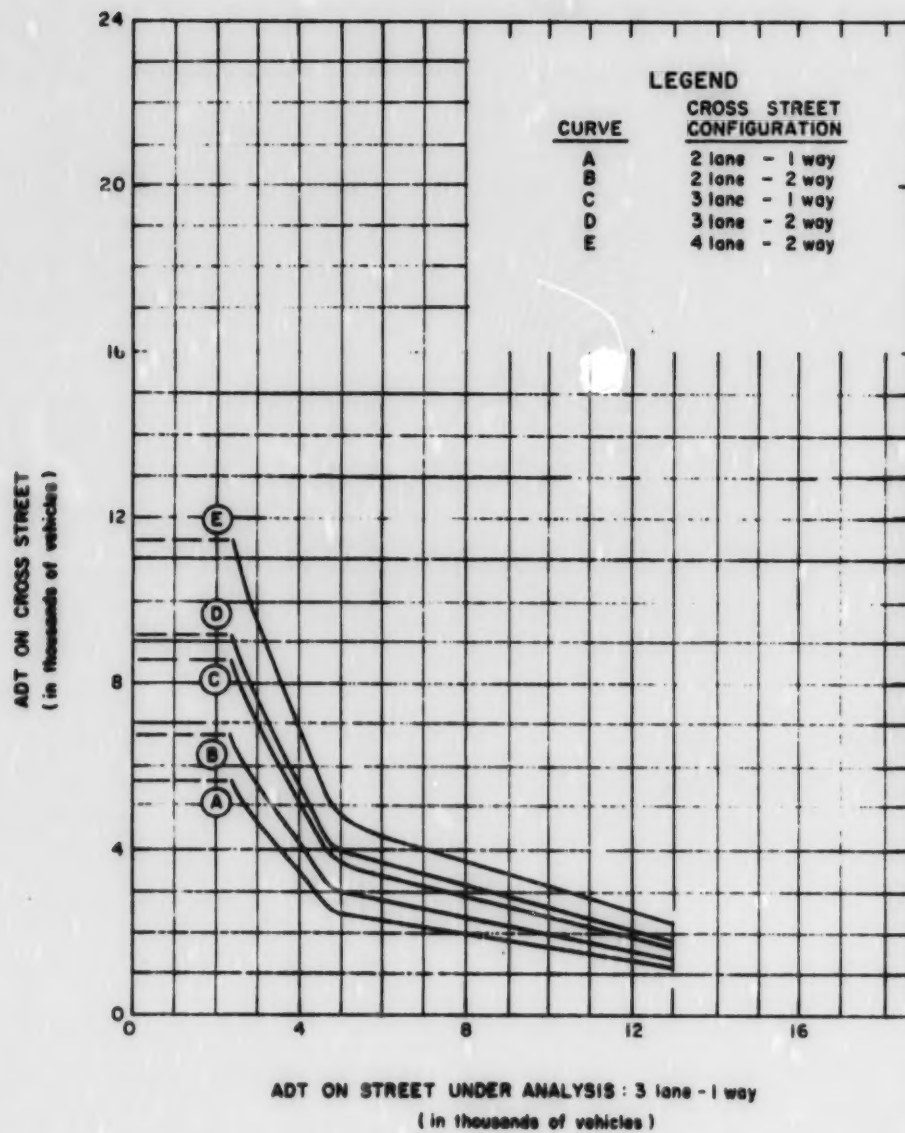


Figure A-6. Critical volumes at signalized intersections.
Analysis of a 3-lane 1-way street

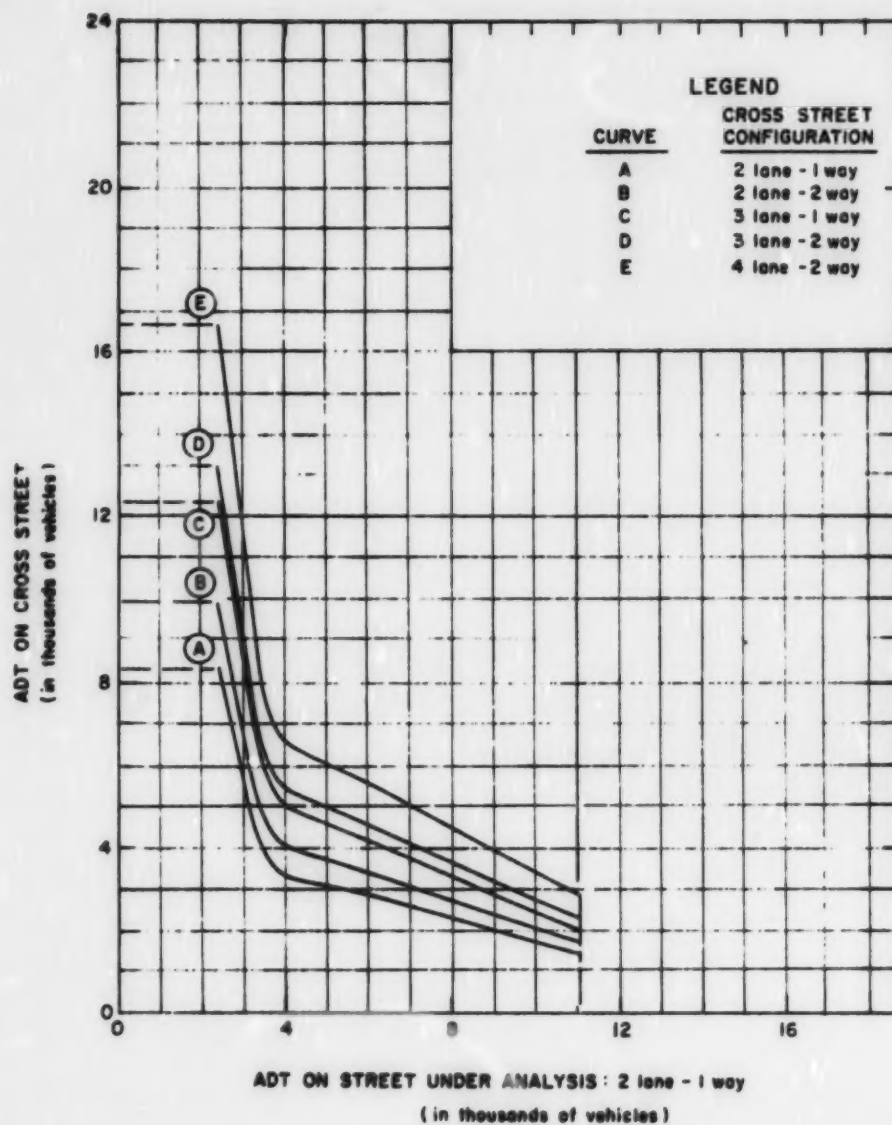


Figure A-7. Critical volumes at signalized intersections.
Analysis of a 2-lane 1-way street

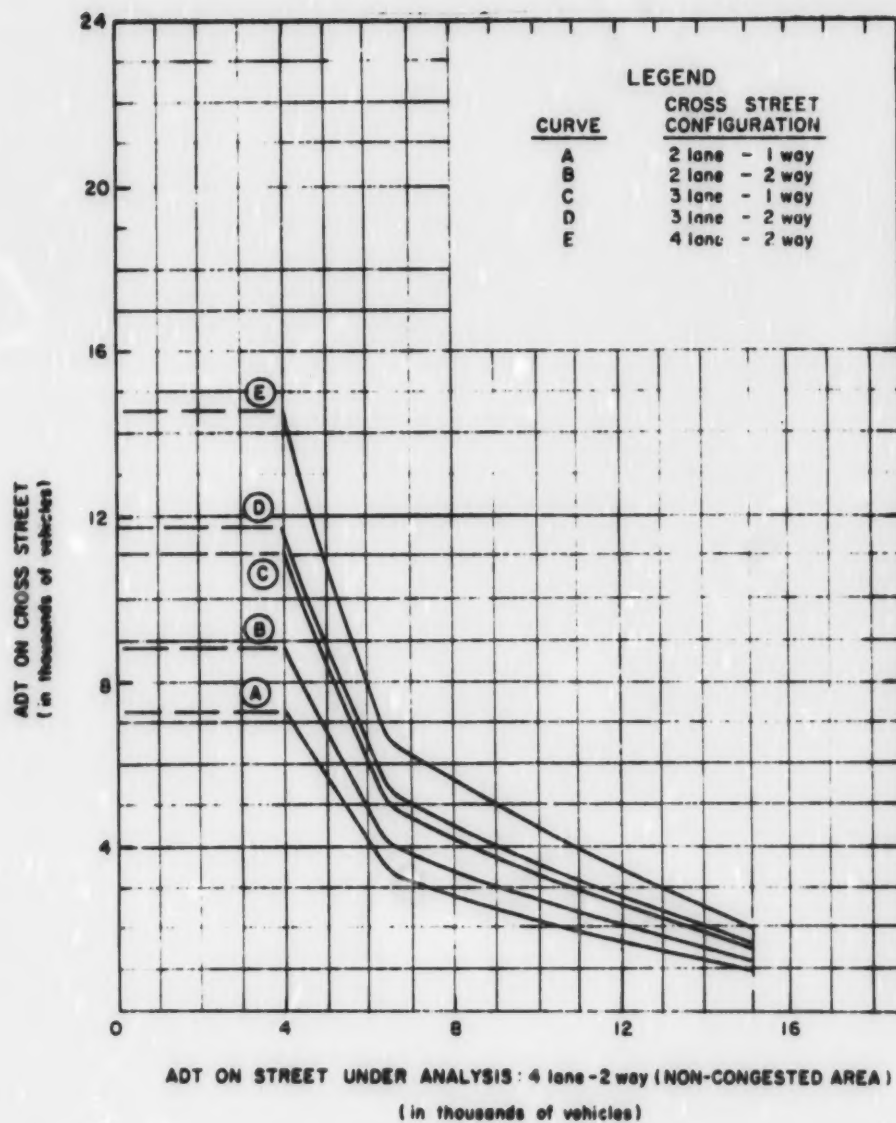


Figure A-8. Critical volumes at signalized intersections. Analysis of a 4-lane 2-way street in a non-congested area

APPENDIX B

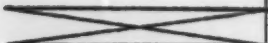
SAMPLE SCREENING WORKSHEETS

PRELIMINARY SCREENING WORK SHEET- SIGNALIZED INTERSECTIONS

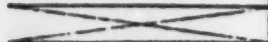
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City/Town: Washington, D.C. State: _____
 Analysis By: R. Dugan Transportation Systems Analyst Date: Sept. 1976
 (name) (title)
 Approved By: T. Midurski Transportation Systems Analyst Date: Sept. 1976
 (name) (title)

- Part I Location: N. Carolina Ave. @ 15th St. NE
- Part II Congested Area? Yes; X No
- Part III Complex Intersection or Special Case? Yes; X No; If yes, enter location on Initial Screening Summary Sheet and proceed to next intersection; if no, proceed with Part IV.
- Part IV Analyze each leg separately on the form, below.

Leg under analysis			Cross-street data							
			Street: <u>15th St</u> Leg: <u>E</u>				Street: _____ Leg: _____			
a Designation	b Adjusted ADT (1977-78)	c Configuration	d Adjusted ADT (1977-78)	e Configuration	f Figure/curve used	g Hot spot indicated?	h Adjusted ADT (1977-78)	i Configuration	j Figure/curve used	k Hot spot indicated?
<u>N. Carolina Ave (E)</u>	<u>19 K</u>	<u>GL-2W</u>	<u>SE</u>	<u>2L-1W</u>		<u>N</u>				
			Street: <u>N. Carolina</u> Leg: <u>E</u>							
<u>15th St. (S)</u>	<u>SE</u>	<u>2L-1W</u>	<u>19 K</u>	<u>GL-2W</u>		<u>N</u>	<u>19 K</u>	<u>GL-2W</u>		<u>N</u>

- Part I Location: CONSTITUTION AVE @ 17th St. NE
- Part II Congested Area? Yes; X No
- Part III Complex Intersection or Special Case? X Yes; _____ No; If yes, enter location on Initial Screening Summary Sheet and proceed to next intersection; if no, proceed with Part IV.
- Part IV Analyze each leg separately on the form, below.

Leg under analysis			Cross-street data							
			Street: _____ Leg: _____				Street: _____ Leg: _____			
a Designation	b Adjusted ADT (1977-78)	c Configuration	d Adjusted ADT (1977-78)	e Configuration	f Figure/curve used	g Hot spot indicated?	h Adjusted ADT (1977-78)	i Configuration	j Figure/curve used	k Hot spot indicated?
			Street: _____ Leg: _____							

Form 2

PRELIMINARY SCREENING WORK SHEET- SIGNALIZED INTERSECTIONS

page 2 of 567

City/Town: Washington, D.C.

State: _____

Analysis By: R. Dugan
(name)

Transportation

Systems Analyst

Date: Sept. 1976

Approved By: T. Midurski
(name)

Transportation

Systems Analyst

(title)

Date: Sept. 1976

Part I Location: Georgia Ave @ Kalmia Rd / Alaska Ave. NW

Part II Congested Area? X Yes; _____ No

Part III Complex Intersection or Special Case? _____ Yes; X No; If yes, enter location on Initial Screening Summary Sheet and proceed to next intersection; if no, proceed with Part IV.

Part IV Analyze each leg separately on the form, below.

Leg under analysis			Cross-street data							
			Street: <u>Kalmia Rd</u> Leg: _____				Street: <u>Alaska Ave</u> Leg: _____			
a Designation	b Adjusted ADT (1977-78)	c Configuration	d Adjusted ADT (1977-78)	e Configuration	f Figure/curve used	g Hot spot indicated?	h Adjusted ADT (1977-78)	i Configuration	j Figure/curve used	k Hot spot indicated?
<u>Georgia Ave (NORTH LEG)</u>	<u>35K</u>	<u>GL-2W</u>	<u>3K</u>	<u>3L-2W</u>	<u>G</u>	<u>N</u>	<u>8K</u>	<u>4L-2W</u>	<u>G</u>	<u>Y</u>
			Street: _____ Leg: _____				Street: _____ Leg: _____			

Part I Location: Kalmia Rd @ 16th St. NW

Part II Congested Area? _____ Yes; X No

Part III Complex Intersection or Special Case? _____ Yes; X No; If yes, enter location on Initial Screening Summary Sheet and proceed to next intersection; if no, proceed with Part IV.

Part IV Analyze each leg separately on the form, below.

Leg under analysis			Cross-street data							
			Street: <u>Kalmia Rd</u> Leg: <u>S.W.</u>				Street: _____ Leg: _____			
a Designation	b Adjusted ADT (1977-78)	c Configuration	d Adjusted ADT (1977-78)	e Configuration	f Figure/curve used	g Hot spot indicated?	h Adjusted ADT (1977-78)	i Configuration	j Figure/curve used	k Hot spot indicated?
<u>16th St. NORTH LEG</u>	<u>31K</u>	<u>4L-2W</u>	<u>6K</u>	<u>3L-2W</u>	<u>G</u>	<u>Y</u>				
			Street: <u>16th St</u> Leg: <u>SOUTH</u>				Street: _____ Leg: _____			
<u>Kalmia Rd EAST LEG</u>	<u>6K</u>	<u>3L-2W</u>	<u>32K</u>	<u>4L-2W</u>	<u>2</u>	<u>Y</u>				

Form 2

PRELIMINARY SCREENING WORK SHEET- SIGNALIZED INTERSECTIONS

page 32 of 567

City/Town: Washington, D.C.

State: _____

Analysis By: R. Dugan

(name)

Transportation

Systems Analyst

Date: Sept. 1976

Approved By: T. Midurski

(name)

Transportation

Systems Analyst

Date: Sept. 1976

(title)

Part I Location: F St @ 9th St NW

Part II Congested Area? Yes; X No

Part III Complex Intersection or Special Case? Yes; X No; If yes, enter location on Initial Screening Summary Sheet and proceed to next intersection; if no, proceed with Part IV.

Part IV Analyze each leg separately on the form, below.

Leg under analysis			Cross-street data							
a Designation	b Adjusted ADT (1977-78)	c Configuration	Street: <u>9th St</u> Leg: <u>South</u>				Street: _____ Leg: _____			
			d Adjusted ADT (1977-78)	e Configuration	f Figure/curve used	g Hot spot indicated?	h Adjusted ADT (1977-78)	i Configuration	j Figure/curve used	k Hot spot indicated?
<u>F St.</u>	<u>8K</u>	<u>GL-2W</u>	<u>17K</u>	<u>4L-2W</u>	<u>G</u>	<u>Y</u>				

Part I Location: F St @ 7th St NW

Part II Congested Area? Yes; X No

Part III Complex Intersection or Special Case? Yes; X No; If yes, enter location on Initial Screening Summary Sheet and proceed to next intersection; if no, proceed with Part IV.

Part IV Analyze each leg separately on the form, below.

Leg under analysis			Cross-street data							
a Designation	b Adjusted ADT (1977-78)	c Configuration	Street: _____ Leg: _____				Street: _____ Leg: _____			
			d Adjusted ADT (1977-78)	e Configuration	f Figure/curve used	g Hot spot indicated?	h Adjusted ADT (1977-78)	i Configuration	j Figure/curve used	k Hot spot indicated?
<u>F St.</u>	<u>7K</u>	<u>GL-2W</u>	<u>17K</u>	<u>4L-2W</u>		<u>Y</u>				

Form 2

APPENDIX C

WASHINGTON, D.C. HOT SPOT SCREENING RESULTS

Intersection	Status			
	Identified as having hot spot potential	Determined not to have hot spot potential	Not analyzed - complex int. or special case	Not analyzed - insufficient data
16th St. at Portal Dr. N.W.	X			
Eastern Ave. at Georgia Ave. N.W.	X			
Georgia Ave. at Kalmia Rd./Alaska Rd. N.W.	X			
Kalmia Rd. at 16th St. N.W.	X			
Alaska Ave. at 13th St. N.W.			X	
16th St. at Holly St. N.W.	X			
Georgia Ave. at Geranium Ave. N.W.	X			
Alaska Ave. at 16th St. N.W.	X			
16th St. at Walter Reed Hospital N.W.	X			
16th St. at Aspen St. N.W.	X			
Georgia Ave. at Dahlia St. N.W.	X			
Georgia Ave. at Butternut St. N.W.	X			
Blair Rd. at Piney Branch Rd. N.W.	X			
Cedar St. at 5th St. N.W.		X		
Piney Branch Rd. at Butternut St. N.W.	X			
Cedar St. at Carroll St. N.W.	X			
Blair Rd. at 4th St./Cedar St. N.W.	X			
Carroll St. at Maple St. N.W.	X			
Carroll St. at Willow St./Eastern Ave. N.W.	X			
Aspen St. at Blair Rd. N.W.	X			
16th St. at Van Buren St. N.W.	X			
Georgia Ave. at Van Buren St. N.W.	X			
Van Buren St. at 5th St. N.W.		X		
Van Buren St. at Blair St. N.W.	X			
16th St. at Sheridan St. N.W.	X			
Georgia Ave. at Piney Branch Rd. N.W.			X	
Piney Branch Rd. at Rittenhouse St. N.W.			X	
Georgia Ave. at Rittenhouse St. N.W.	X			
Sheridan St. at 5th St. N.W.		X		
N. Dakota Ave. at Sheridan St./3rd St. N.W.			X	
N. Capitol St. at Kansas Ave./Chillum Pl.			X	
Kansas Ave. at N. Dakota Ave./Blair Rd.			X	
Missouri Ave. at Military Rd./16th St. N.W.			X	
Missouri Ave. at 14th St. N.W.	X			
Piney Branch Rd. at Ft. Stevens Dr. N.W.			X	
Georgia Ave. at Penbody St. N.W.	X			
Missouri Ave. at 13th St. N.W.	X			
Georgia Ave. at Missouri Ave. N.W.			X	
13th St. at Colorado Ave. N.W.	X			
Georgia Ave. at Madison St. N.W.		X		

Intersection	Status			
	Identified as having hot spot potential	Determined not to have hot spot potential	Not analyzed - complex int. or special case	Not analyzed - insufficient data
Missouri Ave. at 5th St. N.W.	X			
16th St. at Kennedy St. N.W.	X			
14th St. at Kennedy St./Colorado Ave. N.W.			X	
13th St. at Kennedy St. N.W.	X			
Georgia Ave. at Illinois Ave./Kennedy St. N.W.			X	
5th St. at Kennedy St. N.W.	X			
Missouri Ave. at 3rd St. N.W.	X			
Missouri Ave. at Kansas Ave./Kennedy Ave. N.W.			X	
3rd St. at Kennedy St. N.W.		X		
3rd St. at Kansas Ave./Jefferson St. N.W.			X	
16th St. at Colorado Ave. N.W.			X	
Georgia Ave. at Ingraham St. N.W.	X			
13th St. at Callatin St. N.W.		X		
Georgia Ave. at Callatin St. N.W.		X		
5th St. at Callatin St. N.W.		X		
Eastern Ave. at New Hampshire St. N.W.	X			
New Hampshire Ave. at Rittenhouse St./3rd St. N.W.	X			
Rittenhouse St. at Eastern Ave. N.W.	X			
New Hampshire Ave. at Peabody St. N.W.	X			
New Hampshire Ave. at N. Capitol St./Kennedy St. N.W.			X	
Missouri Ave. at New Hampshire Ave./Riggs Rd. N.E.			X	
New Hampshire Ave. at Farragut St. N.E.			X	
Eastern Ave. at Riggs Rd. N.E.	X			
Riggs Rd. at Nicholson St./6th St. N.E.			X	
Riggs Rd. at Chillum Pl. N.E.	X			
S. Dakota Ave. at Riggs Rd. N.E.	X			
Riggs Rd. at Blair Rd./Wt. Totten Dr. N.E.	X			
Riggs Rd. at Missouri Ave./N. Capitol St.			X	
N. Capitol St. at Callatin St.	X			
16th St. at Decatur St. N.W.	X			
Arkansas Ave. at Delafield Pl./13th St. N.W.			X	
Kansas Ave. at Emerson St./5th St. N.W.			X	
16th St. at Allison St. N.W.	X			
Arkansas Ave. at Allison St. N.W.	X			
13th St. at Buchanan St./Iowa Ave. N.W.			X	
Georgia Ave. at Decatur St. N.W.		X		
Georgia Ave. at Buchanan St. N.W.		X		
16th St. at Upshur St. N.W.	X			
14th St. at Arkansas Ave./Vernum St. N.W.			X	
Arkansas Ave. at Upshur St. N.W.	X			

Intersection	Status			
	Identified as having hot spot potential	Determined not to have hot spot potential	Not analysed - complex int. or special case	Not analysed - insufficient data
14th St. at Upshur St. N.W.	X			
Roosevelt High School N.W.			X	
13th St. at Upshur St. N.W.	X			
Georgia Ave. at Kansas Ave./Iowa Ave./Upshur St. N.W.			X	
New Hampshire Ave. at Webster St. N.W.	X			
New Hampshire Ave. at Upshur St. N.W.	X			
5th St. at Upshur St. N.W.	X			
16th St. at Arkansas Ave./Shepherd St. N.W.	X			
Georgia Ave. at Randolph St. N.W.		X		
New Hampshire Ave. at Shepherd St. N.W.			X	
16th St. at Perry Pl. N.W.	X			
Spring Rd. at 14th St. N.W.	X			
Spring Rd. at 13th St. N.W.	X			
Georgia Ave. at New Hampshire Ave. N.W.			X	
16th St. at Oak St. N.W.	X			
Klingie Rd. at Adams Mill Rd./Rosemount Ave. N.W.	X			
Pierce Mill Rd. at Walbridge Pl./Park Rd./Porter Rd. N.W.			X	
Park Rd. at 17th St. N.W.	X			
16th St. at Newton St. N.W.	X			
16th St. at Monroe St. N.W.	X			
14th St. at Sheridan St. N.W.	X			
16th St. at Park Rd. N.W.	X			
14th St. at Monroe St. N.W.	X			
13th St. at Monroe St. N.W.	X			
New Hampshire Ave. at Park Rd. N.W.	X			
Adams Mill Rd. at Kenyon St. N.W.	X			
16th St. at Lamont St. N.W.	X			
14th St. at Park Rd. N.W.			X	
13th St. at Park Rd. N.W.	X			
11th St. at Park Rd. N.W.		X		
Harvard St. at Adams Mill Rd. N.W.	X			
Pleasant St. at Irving St. N.W.	X			
16th St. at Irving St. N.W.	X			
14th St. at Kenyon St. N.W.	X			
14th St. at Irving St. N.W.	X			
13th St. at Kenyon St. N.W.	X			
13th St. at Irving St. N.W.	X			
11th St. at Kenyon St. N.W.	X			
11th St. at Irving St. N.W.	X			
Sherman Ave. at Kenyon St. N.W.	X			

Intersection	Status			
	Identified as having hot spot potential	Determined not to have hot spot potential	Not analyzed - complex int. or special case	Not analyzed - insufficient data
Sherman Ave. at Irving St. N.W.	X			
16th St. at Columbia Rd./Harvard St. N.W.			X	
15th St. at Columbia St. N.W.	X			
16th St. at Columbia Rd. N.W.			X	
Harvard St. at 15th St. N.W.			X	
14th St. at Columbia Rd. N.W.	X			
13th St. at Columbia Rd. N.W.	X			
11th St. at Columbia Rd. N.W.	X			
Columbia Rd. at Sherman Ave. N.W.	X			
14th St. at Harvard St. N.W.	X			
13th St. at Harvard St. N.W.	X			
11th St. at Harvard St. N.W.	X			
Harvard St. at Sherman Ave. N.W.	X			
Calvert St. at Adams Mill Rd. N.W.			X	
Columbia Rd. at 18th St./Calvert St. N.W.	X			
Columbia Rd. at Ontario Rd. N.W.	X			
16th St. at Euclid St. N.W.	X			
15th St. at Euclid St. N.W.	X			
14th St. at Girard St. N.W.	X			
14th St. at Fairmont St. N.W.	X			
Fairmont St. at Sherman Ave. N.W.		X		
14th St. at Euclid St. N.W.	X			
13th St. at Euclid St. N.W.	X			
11th St. at Euclid St. N.W.		X		
Euclid St. at Sherman Ave. N.W.	X			
Kalorama Rd. at Connecticut Ave./Ash Meadow Pl. N.W.			X	
Columbia Rd. at Kalorama Rd. N.W.	X			
Kalorama Rd. at 18th St. N.W.		X		
16th St. at Crescent Pl. N.W.		X		
14th St. at Clifton St. N.W.		X		
13th St. at Clifton St. N.W.	X			
Connecticut Ave. at Columbia Rd./T St. N.W.			X	
Florida Ave. at T St. N.W.	X			
Florida Ave. at 18th St./Vernon St. N.W.	X			
17th St. at U St./Vernon St. N.W.	X			
Florida Ave. at 16th St. N.W.	X			
Florida Ave. at 15th St./W St. N.W.			X	
Florida Ave. at 14th St. N.W.	X			
13th St. at Florida Ave. N.W.	X			
11th St. at Florida Ave. N.W.	X			

Intersection	Status			
	Identified as having hot spot potential	Determined not to have hot spot potential	Not analysed - complex int. or special case	Not analysed - insufficient data
Sherman Ave. at Barry Pl. N.W.		X		
Sherman Ave. at Florida Ave. N.W.	X			
14th St. at W St. N.W.	X			
W St. at 13th St. N.W.	X			
16th St. at V St. N.W.	X			
V St. at 15th St. N.W.		X		
14th St. at V St. N.W.		X		
Georgia Ave. at V St. N.W.	X			
Florida Ave. at V St./Vermont Ave. N.W.			X	
New Hampshire Ave. at U St. N.W.			X	
15th St. at U St. N.W.	X			
U St. at 14th St. N.W.	X			
13th St. at U St. N.W.	X			
U St. at 11th St. N.W.	X			
Vermont St. at U St. N.W.	X			
Florida Ave. at Connecticut Ave. N.W.			X	
Swann St. at 17th St./New Hampshire Ave. N.W.			X	
16th St. at T St. N.W.	X			
15th St. at T St. N.W.	X			
14th St. at T St. N.W.	X			
13th St. at T St. N.W.	X			
10th St. at T St./Vermont St. N.W.			X	
R St. at Connecticut Ave. N.W.			X	
19th St. at R St. N.W.		X		
R St. at 18th St. N.W.	X			
R St. at New Hampshire Ave. N.W.	X			
R St. at 17th St. N.W.	X			
16th St. at S St. N.W.	X			
S St. at 15th St. N.W.	X			
14th St. at S St. N.W.		X		
S St. at 13th St. N.W.	X			
Vermont St. at S St./11th St. N.W.		X		
16th St. at R St. N.W.	X			
15th St. at R St. N.W.	X			
14th St. at R St. N.W.	X			
13th St. at R St. N.W.	X			
Vermont St. at R St./13th St. N.W.				
Connecticut Ave. at Q St. N.W.			X	
Q St. at New Hampshire Ave./16th St. N.W.				
Q St. at 17th St. N.W.	X			

Intersection	Status			
	Identified as having hot spot potential	Determined not to have hot spot potential	Not analysed - complex int. or special case	Not analysed - insufficient data
Q St. at 16th St. N.W.	X			
Q St. at 15th St. N.W.	X			
Q St. at 14th St. N.W.	X			
Q St. at 13th St. N.W.	X			
Q St. at Vermont Ave. N.W.		X		
P St. at 18th St. N.W.	X			
P St. at 17th St. N.W.	X			
P St. at 16th St. N.W.	X			
P St. at 15th St. N.W.	X			
P St. at 14th St. N.W.	X			
Massachusetts Ave. at 18th St. N.W.	X			
Massachusetts Ave. at 17th St. N.W.	X			
Rhode Island Ave. at 15th St. N.W.	X			
Rhode Island Ave. at 14th St. N.W.	X			
Rhode Island Ave. at 17th St. N.W.	X			
M St. at 16th St. N.W.	X			
Massachusetts Ave. at 15th St. N.W.	X			
14th St. at N St./Vermont St. N.W.			X	
M St. at 15th St. N.W.	X			
15th St. at L St. N.W.	X			
L St. at Vermont Ave. N.W.	X			
Vermont St. at K St. N.W.	X			
14th St. at K St. N.W.	X			
14th St. at L St. N.W.	X			
Massachusetts Ave. at 13th St. N.W.	X			
Massachusetts Ave. at L St. N.W.	X			
13th St. at M St. N.W.		X		
L St. at 12th St. N.W.	X			
M St. at 12th St. N.W.		X		
M St. at 11th St. N.W.		X		
N St. at 13th St. N.W.		X		
Rhode Island Ave. at 12th St. N.W.	X			
Q St. at 12th St. N.W.	X			
P St. at 11th St. N.W.		X		
Rhode Island Ave. at 11th St. N.W.	X			
Q St. at 11th St. N.W.		X		
R St. at 11th St. N.W.		X		
S St. at 10th St. N.W.	X			
P St. at 10th St. N.W.		X		
Q St. at 10th St./Rhode Island Ave. N.W.			X	

Intersection	Status			
	Identified as having hot spot potential	Determined not to have hot spot potential	Not analyzed - complex int. or special case	Not analyzed - insufficient data
K St. at 10th St. N.W.	X			
F St. at 9th St. N.W.	X			
Q St. at 9th St. N.W.	X			
Rhode Island at 9th St. N.W.	X			
R St. at 9th St. N.W.	X			
S St. at 9th St. N.W.	X			
Florida Ave. at 9th St./Vermont Ave. N.W.			X	
Q St. at 7th St. N.W.	X			
Rhode Island Ave. at 7th St. N.W.			X	
S St. at 7th St. N.W.	X			
U St. at Florida St./7th St./Georgia Ave. N.W.	X			
V St. at Georgia Ave. N.W.	X			
Georgia Ave. at Bryant St. N.W.	X			
Georgia Ave. at Howard Pl. N.W.		X		
Georgia Ave. at Euclid St. N.W.	X			
Georgia Ave. at Fairmont St. N.W.	X			
Georgia Ave. at Harvard St. N.W.	X			
Georgia Ave. at Columbia Rd. N.W.	X			
Georgia Ave. at Irving St. N.W.	X			
Georgia Ave. at Canyon St. N.W.	X			
Georgia Ave. at Park Rd. N.W.		X		
Georgia Ave. at Princeton Pl. N.W.		X		
R St. at Marion St./Rhode Island Ave. N.W.	X			
R St. at 6th St. N.W.	X			
S St. at 6th St. N.W.	X			
Florida Ave. at 6th St. N.W.			X	
Rhode Island Ave. at New Jersey Ave. N.W.			X	
New Jersey Ave. at Florida Ave. N.W.			X	
4th St. at Bryant St. N.W.	X			
4th St. at Fire Alarm Headquarters N.W.			X	
5th St. at Harvard St. N.W.	X			
Hobart Pl. at Warder St. N.W.				X
Warder St. at Columbia St. N.W.			X	
Warder St. at Irving St. N.W.	X			
Warder St. at Canyon St. N.W.	X			
Warder St. at Otis Pl. N.W.		X		
Park Pl. at Irving St. N.W.	X			
Park Pl. at Canyon St. N.W.	X			
Park St. at Rock Creek/Church Rd. N.W.			X	
Bryant St. at 1st St. N.W.	X			

Intersection	Status			
	Identified as having hot spot potential	Determined not to have hot spot potential	Not analysed - complex int. or special case	Not analysed - insufficient data
1st St. at Michigan Ave. N.W.	X			
Bryant St. at W. Capitol St.	X			
Michigan Ave. at W. Capitol St.	X			
Church Rd. at 2nd St./Upshur St. N.W.			X	
Franklin St. at Lincoln Rd. N.E.	X			
Michigan Ave. at Franklin Rd. N.E.	X			
N. Capitol St. at Harwood Rd./Fort Dr.	X			
Irving St. at Michigan Ave. N.E.	X			
Michigan Ave. at Harwood Rd./4th St. N.E.	X			
Monroe St. at 7th St. N.E.	X			
Michigan Ave. at Monroe St. N.E.	X			
Michigan Ave. at 7th St. N.E.	X			
Taylor St. at Harwood Rd./Fort Dr. N.E.	X			
Hawaii Ave. at Allison St./Clermont Dr. N.E.			X	
N. Capitol St. at Hawaii Ave.			X	
10th St. at Michigan Ave. N.E.				X
Taylor St. at 7th St. N.E.				X
Michigan Ave. at 12th St. N.E.	X			
10th St. at Taylor St. N.E.	X			
Taylor St. at 12th St. N.E.	X			
13th St. at Taylor St./Michigan Ave. N.E.			X	
Vernum St. at 12th St. N.E.				X
Vernum St. at 13th St. N.E.				X
Michigan Ave. at 14th St. N.E.			X	
S. Dakota Ave. at Hamilton St. N.E.	X			
S. Dakota Ave. at Calloway St. N.E.	X			
S. Dakota Ave. at Delsfield St./Emerson St. N.E.	X			
S. Dakota Ave. at Crittenden St./12th St. N.E.			X	
S. Dakota Ave. at Sargent Rd. N.E.	X			
S. Dakota Ave. at Webster St. N.E.				X
S. Dakota Ave. at Michigan Ave. N.E.	X			
Callietin St. at Sargent Rd. N.E.	X			
Eastern Ave. at Sargent Rd. N.E.	X			
Michigan Ave. at 18th St. N.E.	X			
Michigan Ave. at Allison St. N.E.	X			
Eastern Ave. at Michigan Ave. N.E.	X			
Western Ave. at 39th St. N.W.			X	
Western Ave. at 41st St. N.W.			X	
Western Ave. at Wisconsin Ave. N.W.	X			
Western Ave. at 44th St. N.W.		X		

Intersection	Status			
	Identified as having hot spot potential	Determined not to have hot spot potential	Not analysed - complex int. or special case	Not analysed - insufficient data
Western Ave. at Jennifer St. N.W.	X			
Western Ave. between 44th & 45th Sts. N.W.			X	
Western Ave. at River Rd. N.W.	X			
Connecticut Ave. at Oliver St. N.W.	X			
Connecticut Ave. at McKinley St. N.W.	X			
Connecticut Ave. at Livingston St. N.W.	X			
Connecticut Ave. at Military Rd. N.W.	X			
Connecticut Ave. at Jennifer St. N.W.	X			
Connecticut Ave. at Huntington St. N.W.	X			
Connecticut Ave. at Nebraska Ave. N.W.	X			
Connecticut Ave. at 16th St. N.W.			X	
Connecticut Ave. at Davenport St. N.W.	X			
Connecticut Ave. at Brandywine St. N.W.	X			
Connecticut Ave. at Albemarle St. N.W.	X			
Connecticut Ave. at Lums St. N.W.	X			
Connecticut Ave. at Measey Ter. N.W.	X			
Connecticut Ave. at Van Ness St. N.W.	X			
Connecticut Ave. at Tilden St. N.W.	X			
Connecticut Ave. at Sedgwick St. N.W.	X			
Connecticut Ave. at Porter St. N.W.	X			
Connecticut Ave. at Ordway St. N.W.	X			
Connecticut Ave. at Macomb St. N.W.	X			
Connecticut Ave. at Cortland Pl. N.W.	X			
Connecticut Ave. at Jewett St. N.W.	X			
Connecticut Ave. between Jewett & Hawthorne Sts. N.W.	X			
Connecticut Ave. at Cathedral Ave. N.W.	X			
Connecticut Ave. at Woodley Rd. N.W.			X	
Connecticut Ave. at Calvert St. N.W.	X			
Military Rd. at 27th St. N.W.	X			
Military Rd. at 31st St. N.W.	X			
Military Rd. at 32nd St. N.W.	X			
Military Rd. at Nebraska Ave./Broad Branch Rd. N.W.			X	
Military Rd. at Nevada Ave. N.W.	X			
Nevada Ave. at Nebraska Ave. N.W.	X			
41st St. at Livingston St. N.W.	X			
41st St. at Military Rd./Reno Rd. N.W.			X	
Reno Rd. at Chevy Chase Pkwy./Fessenden St. N.W.			X	
Fessenden St. at Nebraska Ave. N.W.		X		
Reno Rd. at Nebraska Ave. N.W.	X			
Reno Rd. at Albemarle St. N.W.	X			

Intersection	Status			
	Identified as having hot spot potential	Determined not to have hot spot potential	Not analyzed - complex int. or special case	Not analyzed - insufficient data
Reno Rd. at Van Ness St. N.W.	X			
Reno Rd. at Tilden St./Springland La. N.W.	X			
Bath St. at Porter St. N.W.				X
Bath St. at Macomb St. N.W.				X
Bath St. at Woodley Rd. N.W.				X
Bath St. at Cleveland Ave. N.W.				X
Cleveland Ave. at 32nd St. N.W.			X	
Cleveland Ave. at 29th St./Calvert St. N.W.			X	
Calvert St. between 28th & 34th Sts. N.W.			X	
Calvert St. at 24th St. N.W.	X			
Wisconsin Ave. at Jennifer St. N.W.	X			
Wisconsin Ave. at Harrison St. N.W.	X			
Wisconsin Ave. at Fessenden St. N.W.	X			
Wisconsin Ave. at 42nd St./Davenport St. N.W.			X	
Wisconsin Ave. at Brandywine St. N.W.	X			
Brandywine St. at 42nd St. N.W.			X	
Nebraska Ave. at Albemarle St. N.W.			X	
Albemarle St. at Wisconsin Ave. N.W.	X			
Albemarle St. at 42nd St.		X		
Wisconsin Ave. at Nebraska Ave./40th St./Yuma St. N.W.			X	
Wisconsin Ave. at Van Ness St. N.W.	X			
Nebraska Ave. at Van Ness St. N.W.	X			
Wisconsin Ave. north of Rodman St. N.W.			X	
Wisconsin Ave. at Rodman St. N.W.	X			
Wisconsin Ave. at Porter St. N.W.	X			
Wisconsin Ave. at Newark St. N.W.	X			
Wisconsin Ave. south of Newark St. N.W.			X	
South Dakota Ave. at Taylor St. N.E.	X			
South Dakota Ave. at 18th St. N.E.	X			
South Dakota Ave. at Quincy St. N.E.	X			
S. Dakota Ave. at 20th St. N.E.			X	
S. Dakota Ave. at Monroe St. N.E.	X	X		
Monroe St. at 22nd Ave. N.E.				
S. Dakota Ave. at Rhode Island Ave. N.E.	X			
S. Dakota Ave. at Carlton Ave. N.E.	X			
S. Dakota Ave. at Vista St. N.E.	X			
S. Dakota Ave. at Bladensburg Rd. N.E.	X			
Monroe Ave. at Rhode Island Ave. N.E.			X	
Eastern Ave. at Rhode Island Ave. N.E.	X			
Eastern Ave. at Bladensburg Rd. N.E.	X			

Intersection	Status			
	Identified as having hot spot potential	Determined not to have hot spot potential	Not analyzed - complex int. or special case	Not analyzed - insufficient data
Eastern Ave. at Minnesota Ave. N.E.	X			
Eastern Ave. at 63rd St. N.E.			X	
58th St. at Grant St. N.E.		X		
Sheriff Rd. at 49th St. N.E.		X		
Grant St. at Division Ave. N.E.	X			
61st St. at E. Capitol St.			X	
Sheriff Rd. at 45th St. N.E.		X		
Denne Ave. at 49th St./Grant St. N.E.			X	
E. Capitol St. at 58th St.	X			
Denne Ave. at Minnesota Ave. N.W.	X			
Denne Ave. at 44th St.			X	
53rd St. at E. Capitol St.	X			
Southern Ave. at Central Ave. S.E.		X		
E. Capitol St. at 49th St.	X			
E. Capitol St. at Central Ave.	X			
Monroe St. at 18th St. N.E.	X			
Rhode Island Ave. at Mills Ave. N.E.	X			
30th St. at Bladensbury St. N.E.	X			
20th St. at Rhode Island Ave. N.E.	X			
14th St. at Monroe St. N.E.	X			
Rhode Island Ave. at 18th St. N.E.			X	
Monroe St. at 12th St. N.E.	X			
Franklin St. at 18th St. N.E.	X			
Bladensbury Rd. at V St./25th Pl. N.E.	X			
10th St. at Monroe St. N.E.	X			
Rhode Island Ave. at Franklin St. N.E.	X			
Bladensbury Rd. at Chapel Rd. N.E.	X			
4th St. at Lincoln Rd. N.E.	X			
Franklin St. at Lincoln Rd. N.E.	X			
Franklin St. at 7th St. N.E.	X			
Franklin St. at 10th St. N.E.	X			
Franklin St. at 12th St. N.E.	X			
Franklin St. at 13th St. N.E.	X			
Franklin St. at 14th St. N.E.		X		
Rhode Island Ave. at Montana Ave. N.E.			X	
Montana Ave. at Bryant St./14th St. N.E.			X	
Montana Ave. at W St./18th St./Adams St. N.E.			X	
New Jersey Ave. at Florida Ave./Rhode Island Ave. N.W.	X			
Florida Ave. at Rhode Island Ave. N.W.			X	
Rhode Island Ave. at 3rd St. N.W.	X			

Intersection	Status			
	Identified as having hot spot potential	Determined not to have hot spot potential	Not analyzed - complex int. or special case	Not analyzed - insufficient data
Rhode Island Ave. at 2nd St. N.W.			X	
Rhode Island Ave. at 1st St. N.W.			X	
N. Capitol St. at Rhode Island Ave.			X	
Rhode Island Ave. at Lincoln Rd. N.E.	X			
Rhode Island Ave. at Summit Pl. N.E.			X	
Rhode Island Ave. at 4th St. N.E.	X			
Rhode Island Ave. at South Ave. N.E.				X
Rhode Island Ave. at 10th St./Bryant St. N.E.			X	
Rhode Island Ave. at 12th St./Saratoga Ave. N.E.			X	
Rhode Island Ave. at 13th St. N.E.	X			
N. Capitol St. at T St.	X			
Lincoln Rd. at T St. N.E.		X		
T St. at 4th St. N.E.		X		
9th St. at T St. N.E.			X	
Brentwood Rd. at 9th St. N.E.	X			
Brentwood Rd. at W St. N.E.	X			
Saratoga Ave. at Brentwood Rd. N.E.	X			
Florida Ave. at 1st St. N.W.	X			
N. Capitol St. at Randolph St.				X
Lincoln Rd. at R St. N.E.	X			
R St. at N. Capitol St.	X			
N. Capitol St. at Quincy St.			X	
Florida Ave. at N. Capitol St.	X			
Florida Ave. at 1st St./Dickington Pl. N.E.	X			
Florida Ave. at 4th St. N.E.	X			
Florida Ave. at 5th St. N.E.	X			
Florida Ave. at 6th St. N.E.	X			
N St. at 6th St. N.E.	X			
Florida Ave. at 8th St. N.E.	X			
Florida Ave. at W. Virginia Ave. N.E.	X			
Florida Ave. at Montello Ave. N.E.			X	
Florida Ave. at 13th St. N.E.	X			
Florida Ave. at Maryland Ave./Benning Rd./N St. N.E.			X	
New York Ave. at Penn St. N.E.	X			
New York Ave. at Brentwood Pkwy. N.E.			X	
New York Ave. at Brentwood Pkwy.-North N.E.	X			
Mt. Olivet Rd. at Brentwood Pkwy.-South N.E.	X			
Mt. Olivet Rd. at Brentwood Pkwy.-North N.E.	X			
New York Ave. at Randall St. N.E.	X			
New York Ave. at Fenwick St. N.E.	X			

Intersection	Status			
	Identified as having hot spot potential	Determined not to have hot spot potential	Not analysed - complex int. or special case	Not analysed - insufficient data
New York Ave. at 16th St. N.E.	X			
New York Ave. at Montana Ave./W. Virginia Ave./18th St. N.E.			X	
New York Ave. between Bladensbury Rd. & Montana Ave. N.E.			X	
New York Ave. between Bladensbury Rd. & Montana Ave. N.E.			X	
Bladensbury Rd. at New York Ave. N.E.	X			
Bladensbury Rd. at Montana Ave. N.E.	X			
W. Virginia Ave. at Mt. Olivet Rd. N.E.	X			
Bladensbury Rd. at Mt. Olivet Rd./17th St. N.E.			X	
17th St. at M St. N.E.	X			
L St. at 17th St. N.E.	X			
K St. at Bladensbury Rd. N.E.	X			
Maryland Ave. at 17th St. N.E.	X			
Benning Rd. at 17th St. N.E.	X			
Benning Rd. at 19th St. N.E.	X			
Benning Rd. at 21st St. N.E.			X	
Benning Rd. at 24th St. N.E.			X	
Benning Rd. at 26th St. N.E.	X			
Benning Rd. at Oklahoma Ave. N.E.	X			
Benning Rd. between Allen & Benning Bridges N.E.			X	
Benning Rd. at Anacostia Ave. N.E.	X			
Benning Rd. at 34th St. N.E.	X			
Benning Rd. at Minnesota Ave. N.E.	X			
Minnesota Ave. at Dix St. N.E.	X			
Benning Rd. at 42nd St. N.E.	X			
Benning Rd. at 44th St. N.E.	X			
Benning Rd. at Texas Ave./E. Capitol St.			X	
Benning Rd. at C St. S.E.			X	
Benning Rd. at G St. S.E.			X	
Benning Rd. at H St. S.E.			X	
New Jersey Ave. at E St. N.W.	X			
1st St. at Q St. N.W.		X		
W. Capitol At. at P St.	X			
New York Ave. at 1st St./Q St. N.E.			X	
M St. at 4th St. N.E.	X			
K St. at 7th St. N.E.	X			
K St. at 8th St. N.E.			X	
M St. at 13th St. N.E.		X		
K St. at 14th St. N.E.		X		
Maryland Ave. at 14th St. N.E.		X		
Calles St. at 17th St. N.E.				X

Intersection	Status			
	Identified as having hot spot potential	Determined not to have hot spot potential	Not analyzed - complex int. or special case	Not analyzed - insufficient data
6th St. at Q St. N.W.				X
New Jersey Ave. at P St. N.W.			X	
O St. at 1st St. N.W.				X
N. Capitol St. at New York Ave.			X	
1st St. at M St. N.E.		X		
7th St. at P St. N.W.	X			
6th St. at P St. N.W.	X			
O St. at 7th St. N.W.	X			
6th St. at O St. N.W.	X			
W St. at 7th St. N.W.			X	
6th St. at M St. N.W.	X			
M St. at 10th St. N.W.		X		
9th St. at M St. N.W.	X			
M St. at 7th St. N.W.	X			
6th St. at M St. N.W.	X			
New York Ave. at New Jersey Ave./ 3rd St./M St. N.W.			X	
New York Ave. at Kirby St. N.W.			X	
1st St. at New York Ave. N.W.	X			
1st St. at M St. N.W.	X			
W. Capitol St. at M St.	X			
L St. at 12th St. N.W.	X			
L St. at 11th St. N.W.			X	
L St. at 10th St. N.W.	X			
9th St. at L St. N.W.	X			
7th St. at L St. N.W.	X			
L St. at 6th St./New York Ave. N.W.			X	
L St. at New York Ave./5th St. N.W.			X	
New York Ave. at 4th St. N.W.			X	
Massachusetts Ave. at 10th St. N.W.			X	
L St. at 1st St. N.W.		X		
12th St. at K St. N.W.	X			
K St. at 11th St. N.W.	X			
10th St. at K St. N.W.	X			
9th St. at Massachusetts Ave. N.W.	X			
Massachusetts Ave. at 7th St. N.W.	X			
6th St. at K St. N.W.	X			
K St. at 5th St. N.W.	X			
K St. at 4th St. N.W.	X			
K St. at 3rd St. N.W.	X			
K St. at New Jersey Ave. N.W.			X	

Intersection	Status			
	Identified as having hot spot potential	Determined not to have hot spot potential	Not analyzed - complex int. or special case	Not analyzed - insufficient data
1st St. at K St. N.W.	X			
N. Capitol St. at K St.	X			
K St. at Cul-de-Sac N.E.				X
1st St. at K St. N.E.	X			
2nd St. at K St. N.E.	X			
3rd St. at K St. N.E.	X			
K St. at 4th St. N.E.	X			
K St. at 5th St. N.E.	X			
K St. at 6th St. N.E.				X
14th St. at I St. N.W.				X
12th St. at I St. N.W.	X			
New York Ave. at 13th St./H St. N.W.			X	
New York Ave. at 12th St. N.W.	X			
11th St. at I St./New York Ave. N.W.			X	
10th St. at New York Ave. N.W.			X	
I St. at 10th St. N.W.		X		
New York Ave. at K St. N.W.			X	
K St. at 7th St./Massachusetts Ave. N.W.			X	
Massachusetts Ave. at 6th St./I St. N.W.	X			
Massachusetts Ave. at 5th St./I St. N.W.			X	
I St. at N. Capitol St.	X			
H St. at 12th St. N.W.	X			
H St. at 11th St. N.W.	X			
H St. at 10th St. N.W.	X			
I St. at 9th St. N.W.	X			
I St. at 7th St. N.W.	X			
I St. at 6th St. N.W.	X			
H St. at 9th St. N.W.	X			
7th St. at H St. N.W.	X			
H St. at 6th St. N.W.	X			
H St. at 5th St. N.W.	X			
Massachusetts Ave. at 4th St. N.W.			X	
Massachusetts Ave. at 3rd St./H St. N.W.			X	
New Jersey Ave. at H St. N.W.	X			
1st St. at H St. N.W.	X			
H St. at N. Capitol St.	X			
H St. at 1st St. N.E.	X			
H St. at 2nd St. N.E.	X			
H St. at 3rd St. N.E.		X		
H St. at 4th St. N.E.	X			

Intersection	Status			
	Identified as having hot spot potential	Determined not to have hot spot potential	Not analysed - complex int. or special case	Not analysed - insufficient data
N St. at 6th St. N.E.		X		
N St. at 7th St. N.E.	X			
N St. at 8th St. N.E.	X			
N St. at 9th St. N.E.		X		
N St. at 10th St. N.E.		X		
N St. at 11th St. N.E.		X		
N St. at 12th St. N.E.	X			
12th St. at C St. N.W.		X		
G St. at 11th St. N.W.	X			
G St. at 10th St. N.W.	X			
G St. at 9th St. N.W.	X			
G St. at 8th St. N.W.		X		
G St. at 7th St. N.W.	X			
G St. at 6th St. N.W.		X		
G St. at 5th St. N.W.		X		
G St. at 4th St. N.W.		X		
G St. at 3rd St. N.W.	X			
Massachusetts Ave. at 2nd St. N.W.	X			
Massachusetts Ave. at New Jersey Ave./1st St. N.W.	X			
N. Capitol St. at G Pl.			X	
F St. at 11th St. N.W.		X		
F St. at 10th St. N.W.	X			
F St. at 9th St. N.W.	X			
F St. at 7th St. N.W.	X			
F St. at 6th St. N.W.	X			
F St. at New Jersey Ave./1st St. N.W.			X	
N. Capitol St. at Massachusetts Ave.			X	
F St. at 4th St. N.E.	X			
F St. at 6th St. N.E.		X		
F St. at 12th St./Maryland Ave. N.E.			X	
Maryland Ave. at 13th St. N.E.		X		
Maryland Ave. at 11th St. N.E.		X		
(Blank)				
E St. at 10th St. N.W.	X			
E St. at 9th St. N.W.	X			
E St. at 8th St. N.W.	X			
E St. at 7th St. N.W.	X			
E St. at 6th St. N.W.	X			
E St. at 5th St. N.W.	X			
E St. at 4th St. N.W.	X			

Intersection	Status			
	Identified as having hot spot potential	Determined not to have hot spot potential	Not analyzed - complex int. or special case	Not analyzed - insufficient data
E St. at 3rd St. N.W.	X			
E St. at 2nd St. N.W.	X			
E St. at 1st St. N.W.	X			
E St. at New Jersey Ave. N.W.	X			
E St. at N. Capitol St.	X			
E St. at Louisiana Ave./			X	
Massachusetts Ave. N.E.				
Massachusetts Ave. at Delaware			X	
Ave. N.E.				
E St. at 4th St. N.E.		X		
E St. at 6th St. N.E.		X		
E St. at 9th St./Maryland Ave.			X	
N.E.				
D St. at 9th St. N.W.	X			
E St. at 7th St. N.W.	X			
D St. at Indiana Ave./6th St. N.W.			X	
D St. at Indiana Ave./3rd St. N.W.			X	
D St. at 1st St. N.W.	X			
D St. at New Jersey Ave. N.W.	X			
D St. at Louisiana/N. Capitol St.			X	
D St. at Delaware Ave. N.E.		X		
D St. at 1st St. N.E.	X			
Massachusetts Ave. at 2nd St. N.E.	X			
D St. at 2nd St. N.E.	X			
D St. at Massachusetts Ave. N.E.	X			
D St. at 4th St. N.E.		X		
D St. at 6th St. N.E.				X
5th St. between C St. & D St. N.E.			X	
Maryland Ave. at Massachusetts			X	
Ave./C St./6th St. N.E.				
Maryland Ave. at 8th St. N.E.		X		
C St. at 8th St. N.E.	X			
C St. at 9th St. N.E.				X
C St. at 11th St. N.E.	X			
C St. at 13th St. N.E.	X			
C St. at Tennessee Ave. N.E.		X		
C St. at 14th St. N.E.	X			
D St. at 15th St. N.E.				X
D St. at 17th St. N.E.				X
C St. at 19th St. N.E.	X			
C St. at 17th St. N.E.	X			
C St. at 18th St. N.E.	X			
C St. at 19th St. N.E.	X			
C St. at 21st St. N.E.	X			

Intersection	Status			
	Identified as having hot spot potential	Determined not to have hot spot potential	Not analyzed - complex int. or special case	Not analyzed - insufficient data
Indiana Ave. at 7th St. N.W.	X			
Indiana Ave. at 7th St. / Pennsylvania Ave. N.W.			X	
C St. at 6th St. N.W.	X			
6th St. at Pennsylvania Ave. / Constitution Ave. N.W.			X	
C St. at 3rd St. N.W.			X	
C St. at 1st St. / Indiana Ave. N.W.			X	
Louisiana Ave. at New Jersey Ave. N.W.			X	
Constitution Ave. at 4th St. at Pennsylvania Ave. N.W.			X	
3rd St. at Pennsylvania Ave. N.W.	X			
Constitution Ave. at Louisiana Ave.	X			
Louisiana Ave. at 1st St. N.W.	X			
Constitution Ave. at 1st St. N.W.	X			
Pennsylvania Ave. at 3rd St. N.W.			X	
New Jersey Ave. at Constitution Ave. N.W.	X			
Delaware Ave. at C St. N.E.		X		
C St. at 1st St. N.E.		X		
C St. at 2nd St. N.E.		X		
C St. at Maryland Ave. / Massachusetts Ave. / 4th Ave. N.E.			X	
C St. at 5th St. N.E.	X			
Constitution Ave. at Delaware Ave. N.E.	X			
Delaware Ave. at Capitol Bldg. N.E.				X
Constitution Ave. at 1st St. N.E.			X	
Maryland Ave. at 1st St. N.E.			X	
Maryland Ave. at Constitution Ave. N.E.			X	
Maryland Ave. at 3rd St. / Constitution Ave. N.E.			X	
Constitution Ave. at 3rd St. N.E.			X	
Constitution Ave. at 6th St. N.E.			X	
Massachusetts Ave. at Constitution Ave. / 7th & 8th Sts. N.E.			X	
Constitution Ave. at 9th St. N.E.				X
Constitution Ave. at 11th St. N.E.	X			
Constitution Ave. at Tennessee Ave. / 13th St. N.E.	X			
N. Carolina Ave. at Constitution Ave. / 14th St. N.E.			X	
N. Carolina Ave. at 15th St. N.E.		X		
Constitution Ave. at 17th St. N.E.			X	
Washington Dr. at 4th St. S.W.				X
Smithsonian Dr. at 3rd St. S.W.				X
Maryland Ave. at 3rd St. S.W.		X		
Independence Ave. at 2nd St. S.W.			X	
Independence Ave. at 1st St. S.W.	X			
S. Capitol St. at Independence Ave.	X			

Intersection	Status			
	Identified as having hot spot potential	Determined not to have hot spot potential	Not analyzed - complex int. or special case	Not analyzed - insufficient data
New Jersey at Capitol Bldg.			X	
New Jersey at Independence Ave. S.E.	X			
1st St. at E. Capitol St.	X			
E. Capitol St. at 2nd St.	X			
E. Capitol St. at 3rd St.		X		
E. Capitol St. at 4th St.	X			
E. Capitol St. at 6th St.		X		
E. Capitol St. at 8th St.	X			
E. Capitol St. at 9th St.				X
E. Capitol St. at Massachusetts Ave./11th St./N. Carolina Ave.			X	
E. Capitol St. at 13th St./Massachusetts Ave./N. Carolina Ave.			X	
E. Capitol St. at 14th St.	X			
E. Capitol St. at 15th St.	X			
E. Capitol St. at 17th St.	X			
E. Capitol St. at 19th St.	X			
Independence Ave. at 1st St. S.E.	X			
Independence Ave. at Pennsylvania Ave./2nd St. S.E.			X	
Pennsylvania Ave. at Independence Ave./3rd St. S.E.			X	
Independence Ave. at 4th St. S.E.	X			
Independence Ave. at 6th St. S.E.				X
Independence Ave. at N. Carolina Ave./7th St./8th St. S.E.			X	
Independence Ave. at 9th St. S.E.				X
N. Carolina Ave. at 10th St. S.E.				X
Independence Ave. at 11th St. S.E.	X			
Independence Ave. at Kentucky Ave./13th St. S.E.			X	
Massachusetts Ave. at 14th St./Independence Ave./15th St. S.E.			X	
Independence Ave. at 17th St. S.E.	X			
Independence Ave. at 19th St. S.E.	X			
1st St. at C St. S.W.			X	
S. Capitol St. at C St. S.W.		X		
C St. at New Jersey Ave. S.W.		X		
C St. at 1st St. S.W.		X		
Pennsylvania Ave. at 4th St. S.E.			X	
Pennsylvania Ave. at N. Carolina Ave. S.E.	X			
N. Carolina Ave. at 6th St. S.E.				X
6th St. at Pennsylvania Ave. S.E.			X	
4th St. at N. Carolina Ave. S.E.			X	
C St. at 11th St. S.E.				X
S. Carolina Ave. at Kentucky Ave. S.E.		X		
Massachusetts Ave. at 17th St. S.E.	X			

Intersection	Status			
	Identified as having hot spot potential	Determined not to have hot spot potential	Not analyzed - complex int. or special case	Not analyzed - insufficient data
S. Carolina Ave. at 11th St. S.E.		X		
Delaware Ave. at D St. S.W.			X	
S. Capitol Ave. at D St.	X			
New Jersey Ave. at D St. S.E.	X			
1st St. at D St. S.E.	X			
2nd St. at D St. S.E.	X			
D St. at 3rd St./N. Carolina Ave. S.E.			X	
Pennsylvania Ave./7th St. S.E.			X	
S. Carolina Ave. at D St./Kentucky S.E.			X	
9th St. at Pennsylvania Ave. S.E.				X
Kentucky Ave. at D St. S.E.			X	
D St. at 15th St. S.E.				X
19th St. at Massachusetts Ave. S.E.	X			
E St. at S. Capitol Ave. S.E.	X			
New Jersey Ave. at N. Carolina Ave./E St. S.E.			X	
E St. at 3rd St. S.E.				X
S. Carolina Ave. at 6th St. S.E.				X
Pennsylvania Ave. at 11th St. S.E.			X	
Pennsylvania Ave. at 12th St. S.E.				X
Potomac Ave. at 17th St. S.E.	X			
Virginia Ave. at 3rd St. S.E.				X
Virginia Ave. at 4th St. S.E.				X
G St. at 11th St. S.E.				X
Pennsylvania Ave. at G St./13th St. S.E.			X	
Kentucky Ave. at Potomac Ave. S.E.			X	
Virginia Ave. at 4th St./I St. S.E.				X
3th St. at I St./Virginia Ave. S.E.			X	
Virginia Ave. at 6th St./I St. S.E.			X	
Virginia Ave. at 7th St./K St. S.E.			X	
Virginia Ave. at 8th St./K St. S.E.			X	
K St. at 11th St. S.E.				X
K St. at 13th St./Potomac Ave. S.E.			X	
Pennsylvania Ave. at Potomac Ave. S.E.			X	
Pennsylvania Ave. at 15th St. S.E.	X			
M St. at Potomac Ave./8th St. S.E.			X	
M St. at 9th St. S.E.	X			
M St. at 11th St. S.E.				X
11th St. at N St. S.E.				X
Pennsylvania Ave. at Kentucky Ave./7th St. S.E.			X	
Ridge Rd. at E. Capitol St.			X	

Intersection	Status			
	Identified as having hot spot potential	Determined not to have hot spot potential	Not analyzed - complex int. or special case	Not analyzed - insufficient data
Ridge St. at 37th St./B St. S.E.			X	
E. Capitol St. at Stoddart Pl. S.E.				X
B St. at Minnesota Ave. S.E.	X			
Minnesota Ave. at Ely Pl. S.E.			X	
Ridge St. at Texas Ave. S.E.	X			
Bowen Rd. at 46th St./Southern Ave. S.E.			X	
Ridge St. at Bowen Rd. S.E.			X	
Alabama Ave. at Massachusetts Ave. S.E.	X			
Minnesota Ave. at Nelson Pl. S.E.			X	
Minnesota Ave. at Pennsylvania Ave. S.E.			X	
Pennsylvania Ave. at 27th St. S.E.	X			
Pennsylvania Ave. at 28th St. S.E.				X
Pennsylvania Ave. at 30th St. S.E.	X			
Pennsylvania Ave. at Branch Ave. S.E.			X	
Pennsylvania Ave. at 38th St./Alabama Ave. S.E.			X	
Pennsylvania Ave. at Southern Ave. S.E.	X			
Naylor St. at Minnesota Ave. S.E.			X	
Branch Ave. at Alabama Ave. S.E.	X			
Alabama Ave. at 30th St. S.E.				X
Alabama Ave. at Good Hope Rd. S.E.	X			
Good Hope Rd. at Naylor Rd. S.E.	X			
Naylor Rd. at Alabama Ave. S.E.	X			
Alabama Ave. at 25th Ave. S.E.	X			
Naylor Rd. at 30th St./Gainsville St. S.E.			X	
Good Hope Rd. at M.L. King Jr. Ave. S.E.	X			
Good Hope Rd. at 13th St. S.E.	X			
Good Hope Rd. at 14th St. S.E.				X
Good Hope Rd. at Minnesota Ave. S.E.	X			
Good Hope Rd. at 16th St. S.E.	X			
Naylor Rd. at Suitland Pkwy. S.E.	X			
Alabama Ave. at Irving St./Jasper St. S.E.			X	
Suitland Pkwy. at Southern Ave. S.E.	X			
Massachusetts Ave. at 49th St. N.W.			X	
Massachusetts Ave. at 46th St./University Ave. N.W.			X	
Van Ness at 46th St. N.W.		X		
Yuma Ave. at 46th St. N.W.			X	
Massachusetts Ave. west of Ward Circle N.W.			X	
Massachusetts Ave. east of Quebec St. N.W.			X	
Idaho St. at 39th St. N.W.				X
Woodley Rd. at Wisconsin Ave. N.W.	X			

Intersection	Status			
	Identified as having hot spot potential	Determined not to have hot spot potential	Not analyzed - complex int. or special case	Not analyzed - insufficient data
Massachusetts Ave. at Cathedral Ave. N.W.			X	
Garfield Ave. at Wisconsin Ave. N.W.	X			
Massachusetts Ave. at Garfield Ave. N.W.	X			
(Blank)				
Garfield Ave. at Reno Rd. N.W.	X			X
Observatory Circle at Reno Rd. N.W.				X
Massachusetts Ave. at Normanstone St. N.W.				
Massachusetts Ave. at Rock Creek Rd. N.W.	X			
Massachusetts Ave. at Belmont Rd. N.W.	X			
Massachusetts Ave. at California Ave. N.W.				X
Massachusetts Ave. at S St. N.W.	X			
Florida Ave. at R St. N.W.	X			
Massachusetts Ave. at R St. N.W.	X			
Florida Ave. at Massachusetts Ave. N.W.			X	
Massachusetts Ave. at Q St. N.W.	X			
Massachusetts Ave. at Connecticut Ave. N.W.			X	
Massachusetts Ave. at 20th St. N.W.	X			
P St. at 20th St. N.W.	X			
21st St. at P St. N.W.	X			
Q St. at 23rd St. N.W.			X	
P St. at 23rd St. N.W.			X	
P St. at 22nd St. N.W.	X			
Connecticut Ave. at N St. N.W.			X	
Connecticut Ave. at Jefferson Pl. N.W.			X	
Connecticut Ave. at M St. N.W.			X	
M St. at 17th St. N.W.	X			
17th St. at De Bal St. N.W.				X
Connecticut Ave. at De Bal St. N.W.				X
16th St. at L St. N.W.	X			
17th St. at L St. N.W.	X			
Connecticut Ave. at K St. N.W.	X			
15th St. at K St. N.W.	X			
16th St. at K St. N.W.	X			
16th St. at I St. N.W.	X			
Connecticut Ave. at K St./17th St. N.W.	X			
17th St. at K St. N.W.	X			
17th St. at I St./Jackson Pl. N.W.	X			
17th St. at I St. N.W.	X			
McArthur Blvd. at Loughboro Blvd. N.W.	X			
Loughboro Blvd. at Sibley Hosp. N.W.				X

Intersection	Status			
	Identified as having hot spot potential	Determined not to have hot spot potential	Not analyzed - complex int. or special case	Not analyzed - insufficient data
Canal Rd. at Chain Bridge N.W.	X			
Canal Rd. at Arizona Ave. N.W.	X			
McArthur Blvd. at Arizona Ave. N.W.	X			
McArthur Blvd. at Dana Pl. N.W.				X
Nebraska Ave. at Foxhall Rd. N.W.	X			
Nebraska Ave. at Newark Ave. N.W.			X	
Nebraska Ave. at New Mexico Ave. N.W.	X			
Garfield Ave. at Foxhall Rd. N.W.			X	
Wisconsin Ave. north of Davis Rd. N.W.				X
Calvert Rd. at 37th St./Wisconsin Ave. N.W.			X	
Wisconsin Ave. at W Pl. North N.W.				X
Wisconsin Ave. at W Pl. South N.W.				X
Wisconsin Ave. at Whitehaven Pkwy. N.W.		X		
Wisconsin Ave. at 34th St. N.W.				X
Wisconsin Ave. at R St. N.W.	X			
Wisconsin Ave. at Q St. N.W.	X			
Wisconsin Ave. at P St. N.W.	X			
Wisconsin Ave. at Dumbarton St./O St. N.W.				X
Wisconsin Ave. at N St. N.W.	X			
Wisconsin Ave. at M St. N.W.	X			
30th St. at Q St. N.W.				X
Q St. at 28th St. N.W.	X			
30th St. at P St. N.W.				X
P St. at 28th St. N.W.	X			
MacArthur Blvd. at V St. N.W.				X
MacArthur Blvd. at Whitehaven Pkwy./Reservoir Rd. N.W.			X	
MacArthur Blvd. at Reservoir Rd. N.W.			X	
Reservoir Rd. at Foxhall Rd. N.W.			X	
Foxhall Rd. at D St. N.W.				X
MacArthur Blvd. at D St. N.W.				X
Foxhall Rd. at MacArthur Blvd. N.W.			X	
Archbold Pkwy. at Canal Rd./MacArthur Blvd. N.W.			X	
Canal Rd. at Whitehurst Freeway N.W.	X			
Canal Rd. at Francis Scott Key Bridge N.W.	X			
M St. at 34th St. N.W.	X			
M St. at 33rd St. N.W.	X			
M St. at 31st St. N.W.				X
M St. at 30th St. N.W.				X
M St. at Pennsylvania Ave. N.W.			X	
M St. at 23th St. N.W.		X		

Intersection	Status			
	Identified as having hot spot potential	Determined not to have hot spot potential	Not analyzed - complex int. or special case	Not analyzed - insufficient data
W St. at 24th St. N.W.	X			
M St. at 25th St. N.W.	X			
M St. at 22nd St. N.W.	X			
M St. at New Hampshire Ave. N.W.	X			
M St. at 21st St. N.W.			X	
M St. at 20th St. N.W.	X			
M St. at 19th St. N.W.	X			
New Hampshire Ave. at 20th St. N.W.			X	
Reservoir Rd. at 38th St. N.W.				X
Reservoir Rd. at 35th St. N.W.	X			
Reservoir Rd. at 34th St. N.W.		X		
Q St. at 34th St. N.W.		X		
Q St. at 33rd St. N.W.		X		
22nd St. at New Hampshire Ave. N.W.	X			
Pennsylvania Ave. at 26th St. N.W.				X
Pennsylvania Ave. at 25th St. N.W.			X	
L St. at 23rd St. N.W.	X			
L St. at 22nd St. N.W.			X	
L St. at 21st St. N.W.	X			
L St. at 20th St. N.W.	X			
L St. at 19th St. N.W.	X			
L St. at 18th St. N.W.	X			
K St. at 25th St. N.W.	X			
K St. at 24th St. N.W.			X	
K St. at Pennsylvania Ave. N.W.			X	
Pennsylvania Ave. at 22nd St. / K St. N.W.			X	
K St. at 22nd St. N.W.			X	
K St. at 21st St. N.W.	X			
K St. at 20th St. N.W.	X			
K St. at 19th St. N.W.	X			
K St. at 18th St. N.W.	X			
Virginia Ave. at Potomac Pkwy. N.W.	X			
Virginia Ave. at 27th St. N.W.				X
I St. at 23rd St. N.W.	X			
Pennsylvania Ave. at 21st St. N.W.				X
I St. at 20th St. N.W.	X			
I St. at 19th St. N.W.	X			
I St. at 18th St. N.W.	X			
I St. at Pennsylvania Ave. / 20th St. N.W.			X	
Virginia Ave. at New Hampshire Ave. N.W.			X	

Intersection	Status			
	Identified as having hot spot potential	Determined not to have hot spot potential	Not analyzed - complex int. or special case	Not analyzed - insufficient data
H St. at 23rd St. N.W.	X			
Pennsylvania Ave. at H St./19th St. N.W.			X	
H St. at 18th St. N.W.	X			
H St. at 17th St. N.W.	X			
Connecticut Ave. at H St. N.W.	X			
H St. at 16th St. N.W.	X			
G St. at 23rd St. N.W.	X			
G St. at 22nd St. N.W.		X		
G St. at 21st St. N.W.		X		
G St. at 20th St. N.W.	X			
G St. at 19th St. N.W.	X			
G St. at 18th St. N.W.	X			
Pennsylvania Ave. at 17th St. N.W.			X	
Pennsylvania Ave. at Jackson Ave./W. Executive Ave. N.W.	X			
Virginia Ave. at 23rd St./F St. N.W.			X	
F St. at 19th St. N.W.	X			
F St. at 18th St. N.W.	X			
New York Ave. at 17th St. N.W.	X			
17th St. at F St. N.W.	X			
23rd St. at E St. N.W.				X
Virginia Ave. at 22nd St./E St. N.W.			X	
E St. at 21st St. N.W.		X		
E St. at 20th St. N.W.			X	
E St. at 19th St. N.W.	X			
E St. at New York Ave./18th St. N.W.	X			
New York Ave. at 17th St. N.W.	X			
Virginia Ave. at 21st St. N.W.			X	
New York Ave. at 20th St. N.W.	X			
E St. at 19th St. N.W.	X			
E St. at 18th St. N.W.	X			
Virginia Ave. at 20th St. N.W.	X			
23rd St. at C St. N.W.	X			
C St. at 21st St. N.W.		X		
Constitution Ave. at 23rd St. N.W.			X	
Constitution Ave. at National Academy of Science N.W.				X
Constitution Ave. at Independence Dr. N.W.				X
Constitution Ave. at 21st St. N.W.	X			
Pennsylvania Ave. at E St. N.W.			X	
Constitution Ave. at 20th St. N.W.	X			
Constitution Ave. at 19th St. N.W.	X			

Intersection	Status			
	Identified as having hot spot potential	Determined not to have hot spot potential	Not analyzed - complex int. or special case	Not analyzed - insufficient data
Vermont Ave. at I St. N.W.	X			
15th St. at I St. N.W.	X			
H St. at Vermont Ave. N.W.	X			
H St. at 15th St./Madison Ave. N.W.	X			
H St. at 14th St. N.W.	X			
Pennsylvania Ave. at Madison East N.W.	X			
Pennsylvania Ave. at New York Ave./15th St./G St. N.W.			X	
New York Ave. at 14th St. N.W.	X			
G St. at 14th St. N.W.	X			
G St. at 13th St. N.W.	X			
F St. at 15th St. N.W.	X			
F St. at 14th St. N.W.	X			
F St. at 13th St. N.W.	X			
F St. at 12th St. N.W.	X			
Pennsylvania Ave. at Madison East N.W.	X			
Pennsylvania Ave. at 15th St. N.W.	X			
Pennsylvania Ave. at E St./14th St. N.W.			X	
E St. at 13th St. N.W.	X			
E St. at 12th St. N.W.	X			
E St. at 11th St. N.W.	X			
E St. at 17th St. N.W.	X			
E St. at S. Executive Ave. N.W.	X			
E St. at E. Executive Ave./Ellipse Rd. N.W.	X			
E St. at 15th St. N.W.	X			
E St. at Pennsylvania Ave. N.W.			X	
Pennsylvania Ave. at 13th St. N.W.			X	
Pennsylvania Ave. at 12th St. N.W.	X			
Pennsylvania Ave. at 11th St./D St. N.W.			X	
Pennsylvania Ave. at 10th St. N.W.			X	
Pennsylvania Ave. at 9th St. N.W.			X	
Virginia Ave. at 18th St. N.W.	X			
Virginia Ave. at Constitution Ave. N.W.	X			
Constitution Ave. at 17th St. N.W.			X	
Constitution Ave. at 16th St. N.W.	X			
Constitution Ave. at 15th St. N.W.	X			
Constitution Ave. at 14th St. N.W.	X			
Constitution Ave. at 12th St. N.W.	X			
Constitution Ave. at 11th St. N.W.	X			
Constitution Ave. at 9th St. N.W.	X			
Constitution Ave. at 7th St. N.W.	X			

Intersection	Status			
	Identified as having hot spot potential	Determined not to have hot spot potential	Not analyzed - complex int. or special case	Not analyzed - insufficient data
7th St. at Madison Dr. S.W.				X
7th St. at Washington Dr. S.W.				X
14th St. at Smithsonian Dr. S.W.				X
7th St. at Smithsonian Dr. S.W.				X
14th St. at Jefferson Dr. S.W.				X
Independence Ave. at 15th St. S.W.	X			
Independence Ave. at 14th St. S.W.	X			
Independence Ave. at 12th St. S.W.			X	
Independence Ave. at 10th St. S.W.				X
Independence Ave. at 9th St. S.W.	X			
Independence Ave. at 7th St. S.W.	X			
Independence Ave. at 6th St. S.W.	X			
Independence Ave. at Maryland Ave./ 4th St. S.W.	X			
Independence Ave. at 3rd St. S.W.	X			
14th St. at C St. S.W.	X			
C St. at 12th St. S.W.	X			
C St. at Maryland Ave./7th St. S.W.		X		
Maryland Ave. at 6th St. S.W.		X		
6th St. at C St. S.W.		X		
C St. at 4th St. S.W.	X			
C St. at 3rd St. S.W.	X			
C St. at 2nd St. S.W.				X
15th St. at Maine Ave. S.W.	X			
Maine Ave. at 15th St. Ramp S.W.	X			
14th St. at Tidal Basin Approach S.W.				X
D St. at 12th St. S.W.		X		
Maryland Ave. at 10th St. S.W. (Blank)				X
9th St. at D St. S.W.				X
D St. at 7th St. S.W.	X			
E St. at 7th St. S.W.	X			
F St. at 4th St. S.W.	X			
Maine Ave. at 10th St. S.W.			X	
Virginia Ave. at S. Capitol Ave.				X
G St. at 7th St. S.W.	X			
G St. at 4th St. S.W.	X			
10th St. at Maine Ave. S.W.			X	
Maine Ave. at 9th St. S.W.			X	
I St. at 7th St. S.W.			X	
I St. at 6th St. S.W.		X		

Intersection	Status			
	Identified as having hot spot potential	Determined not to have hot spot potential	Not analyzed - complex int. or special case	Not analyzed - insufficient data
I St. at 4th St. S.W.	X			
I St. at 3rd St. S.W.	X			
I St. at Delaware Ave. S.W.				
I St. at S. Capitol St. S.W.		X		X
Maine Ave. at M St. S.W.	X			
M St. at 6th St. S.W.	X			
M St. at 4th St. S.W.	X			
M St. at 3rd St. S.W.	X			
M St. at Canal St. S.W.				X
M St. at Half St. S.W.	X			
M St. at S. Capitol St. S.W.	X			
M St. at 1st St./New Jersey St. S.E.	X			
M St. at 2nd St. S.E.				X
N St. at 4th St. S.E.				X
S. Capitol St. at Suitland Pkwy. Botanic Gardens			X	
Firth-Sterling at Suitland Pkwy. S.E.	X		X	
W St. at M. L. King Jr. Ave. S.E.	X			
Morris Rd. at M. L. King Jr. Ave. S.E.	X			
Howard Rd. at M. L. King Jr. Ave. S.E.				X
Stanton Rd. at M. L. King Jr. Ave. S.E.	X			
M. L. King Jr. Ave. at St. Elisabeth's Hosp. S.E.				X
Rife St. at 17th St. S.E.				X
Neanton Rd. at Suitland Pkwy. S.E.			X	
23rd St. at Alabama Ave. S.E.	X			
Alabama Ave. at Stanton Ter. S.E.			X	
Bruse St. at Stanton Rd. S.E.				X
Stanton Rd. at Alabama Ave. S.E.	X			X
Alabama Ave. at Congress St. S.E.				X
M. L. King Jr. Ave. south of Milwaukee Pl. S.E.				X
S. Capitol St. at Portland Rd. S.E.	X			
M. L. King Jr. Ave. at Portland Rd. S.E.	X			
Alabama Ave. at Wheeler Rd. S.E.	X			
Wheeler Rd. at Mississippi Ave. S.E.	X			
Valley Ave. at Wheeler Rd. S.E.	X			
Wahler Pl. at Wheeler Rd. S.E.				X
Barnaby St. at Wheeler Rd. S.E.				X
Southern Ave. at Wheeler Rd. S.E.	X			
Alabama Ave. at Randle Pl. S.E.	X			
Alabama Ave. at 13th St. S.E.			X	

Intersection	Status			
	Identified as having hot spot potential	Determined not to have hot spot potential	Not analyzed - complex int. or special case	Not analyzed - insufficient data
M. L. King Jr. Ave. at Trenton Pl. S.E.				X
S. Capitol St. at M. L. King Jr. Ave. S.E.			X	
4th St. at Mississippi Ave. S.E.			X	
Atlantic St. at 4th St. S.E.			X	
Atlantic St. at 1st St. S.E.	X			
Atlantic St. at Mississippi Ave. S.E.			X	
Chesapeake St. at S. Capitol St. S.E.	X			
S. Capitol St. at Elmira St. S.E.				X
Galveston St. at 1st St./S. Capitol St. S.E.			X	
S. Capitol St. at Livingston St. S.E.	X			
S. Capitol St. at Southern Ave. S.E.	X			
M. L. King Jr. Ave. at Chesapeake St. S.E.	X			
Chesapeake St. at Overlook Ave.				X

APPENDIX D

APPLICATION OF THE HOT SPOT GUIDELINE TECHNIQUES: DETAILED DISCUSSION

The purpose of this appendix is to provide a detailed description of the techniques used in applying the Hot Spot Guidelines¹ to the study of potential carbon monoxide problems in Washington, D.C. To accomplish this, each of the three phases of the Guidelines procedure is discussed using the analysis of the Wisconsin Avenue - Albemarle Street intersection as an example.

HOT SPOT SCREENING

As indicated in Section III, numerous data elements required during application of the Guidelines were obtained from the District of Columbia Department of Transportation, Bureau of Traffic Engineering and Operations. The first of these used in the screening analysis was a traffic signal locations map; this map identified the specific locations to be analyzed since the scope of the project specified that only signalized intersections were to be considered. The street names for each signalized intersection identified from the traffic signal locations map were entered on a Screening Worksheet; Figure D-1, below shows the worksheet for the example intersection.

The next step involved determining several general features of the intersection based on a traffic volume map, a street log, and general knowledge of the city. The data provided by the volume map and street log were sufficient to identify the basic configuration of the intersection and to

Part I Location: Wisconsin Avenue at Albemarle St. NW

Part II Congested Area? Yes ☒ No ☐

Part III Complex Intersection or Special Case? Yes ☐ No ☒ If yes, enter location on Initial Screening Summary Sheet and proceed to next intersection; if no, proceed with Part IV.

Part IV Analyze each leg separately on the form, below.

Leg under analysis			Cross-street data							
			Street: _____ Leg: _____				Street: _____ Leg: _____			
a Designation	b Adjusted ADT (1977-78)	c Configur- ation	d Adjusted ADT (1977-78)	e Configur- ation	f Figure/ curve used	g Net spot indicated	h Adjusted ADT (1977-78)	i Configur- ation	j Figure/ curve used	k Net spot indicated

Figure D-1. Sample worksheet used in the preliminary screening of Washington, D.C.

determine whether or not to consider the intersection to be complex or a special case.* The maps provided by the Bureau of Traffic Engineering and Operations indicated that the Wisconsin Avenue - Albemarle Avenue intersection is a basic cross intersection. The volume map indicated that the daily traffic volumes were about 7,000 on Albemarle Street and about 28,000 on Wisconsin Avenue. From this information, then, it was established that the intersection of Wisconsin Avenue and Albemarle Street was neither complex nor a special case as defined by the Guidelines. Also, from a general knowledge of the city, it was assumed that the intersection is not located in a congested area nor was it located in a street canyon. Generally, congested areas are those where substantial interference occurs within a traffic stream as a result of a high rate of activity with respect

* Complex intersections are defined in the Guidelines as intersections with unusual geometry (more than four legs) or very high volumes on all legs; special cases are defined as intersections controlled by traffic officers or with special signal control during specific hours of the day.

to turning movements, pedestrian crossings, parking and unparking maneuvers, etc.; this type of activity occurs most frequently in the central business district. Based on this information, Parts I, II and III of the worksheet were completed as shown in Figure D-1.

Since Part III of the worksheet indicated that the intersection is neither complex nor a special case, the analysis continued. If it had been indicated that the intersection was either complex or a special case, further analysis using the screening procedure would not have been appropriate; rather, the intersection would be considered for further analysis using the more detailed verification procedure.

At this point, several entries were made in Part IV of the worksheet. The designation of the first leg to be analyzed was entered in column a, and the corresponding volume and configuration entered in columns b and c, respectively. As an example, the designation for the south leg of Wisconsin Avenue was entered in column a as *Wisconsin South*. The value entered in column b was an adjusted ADT derived by increasing the ADT indicated on the volume map by 8 percent and rounding to the nearest thousand. For the south leg of Wisconsin Avenue, the flow map indicated an ADT of 28,000; increasing this by 8 percent yielded 30,240, which was rounded to 30,000. This was done to more closely reflect 1977 ADT (the flow map represented 1975 ADT). The entry in column c identified the number of lanes and the directional use (one-way or two-way operation) of the south leg of Wisconsin Avenue. The entry *4L-2W* indicates a four-lane, two-way facility. The street leg provided the total pavement width of each street section in the city; an estimate of the number of lanes for any particular section was obtained by dividing the pavement width by the width of an "average" traffic lane (3 to 3.5 meters). The traffic signal locations map showed the location and direction of all one-way streets in the city.

The next entry involved the cross-street data. The designation of the cross-street (with respect to the south leg of Wisconsin Avenue) was entered

on the first line as *Albemarle west* and *Albemarle east*. The adjusted ADT's for the west leg and east leg of Albemarle Street were entered in columns d and h, respectively, and the configurations for both were entered in columns e and i. The information entered in these columns was derived in the same manner as the data entered in columns b and c for Wisconsin Avenue, as described previously. The worksheet at this point is shown in Figure D-2, below.

The next step involved selecting the appropriate screening nomograph from the Hot Spot Guidelines. Eight separate nomographs are provided in the Guidelines for screening signalized intersections (see Appendix A). Selection of the particular nomograph is based on the configuration of the intersection leg being analyzed; in this instance, the leg under analysis has a four-lane, two-way configuration, therefore the nomograph for four-lane, two-way streets in noncongested areas was selected. Each nomograph

Part I Location: Wisconsin Avenue at Albemarle St. NW

Part II Congested Area? Yes ☒ No ☐

Part III Complex Intersection or Special Case? Yes ☒ No ☐ If yes, enter location on Initial Screening Summary Sheet and proceed to next intersection; if no, proceed with Part IV.

Part IV Analyze each leg separately on the form, below.

Leg under analysis			Cross-street data							
			Street: <u>Albemarle</u> Leg: <u>West</u>				Street: <u>Albemarle</u> Leg: <u>East</u>			
<u>d</u> Designation	<u>h</u> Adjusted ADT (1977-78)	<u>e</u> Config- uration	<u>d</u> Adjusted ADT (1977-78)	<u>e</u> Config- uration	<u>f</u> Figure/ curve used	<u>g</u> Hot spot indicated	<u>h</u> Adjusted ADT (1977-78)	<u>i</u> Config- uration	<u>j</u> Figure/ curve used	<u>k</u> Hot spot indicated
Wisconsin South	30E	4L-2W	8E	2L-2W			8E	2L-2W		

Figure D-2. Screening worksheet

includes five curves corresponding to five cross-street configurations. Since the cross-street (Albemarle) configuration was identified as two-lane, two-way, curve B was selected. The figure number (as it appears in the Hot Spot Guidelines) corresponding to the nomograph for four-lane, two-way streets in noncongested areas, and the cross-street curve designation were entered in columns f and j of the worksheet.

To determine whether or not the south leg of Wisconsin Avenue is a potential hot spot, its volume (from column b) and the cross-street volume (from column d) were used as the x-coordinate and y-coordinate, respectively, to locate a point on the nomograph (see Figure D-3); as can be seen, this point lies well beyond curve B on the nomograph, implying that hot spot potential exists on the south leg of Wisconsin Avenue. The completed worksheet is shown in Figure D-4.

The intersection name and result of the screening were then entered on a summary sheet (see Appendix C). Since the screening indicated that hot spot potential did exist, this intersection was further analyzed using the hot spot verification process as described in the following paragraphs.

HOT SPOT VERIFICATION

Ordinarily, hot spot verification would be conducted at each location identified in the screening process as having hot spot potential or being either a complex intersection or special case. For the purposes of this project, however, the verification process was applied to only 29 locations throughout the city.

The first step in the hot spot verification process was to assemble the appropriate data regarding various traffic operating characteristics and the physical layout of the intersection being analyzed. The first element obtained for each location was a site sketch showing:

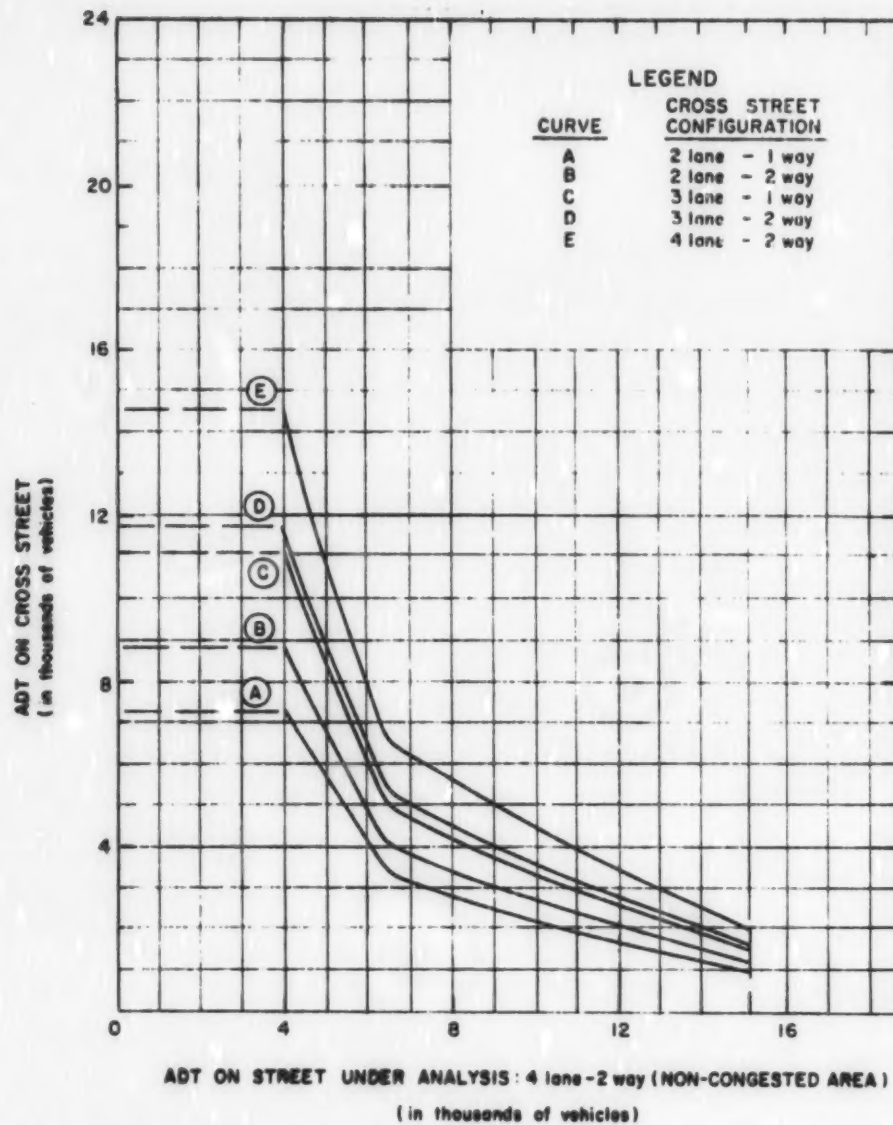


Figure D-3. Critical volumes at signalized intersections. Analysis of a 4-lane 2-way street in a non-congested area

Part I Location: Wisconsin Avenue at Albemarle St. NW

Part II Congested Area? Yes: X No.

Part III Complex Intersection or Special Case? Yes: X No; If yes, enter location on Initial Screening Summary Sheet and proceed to next intersection; if no, proceed with Part IV.

Part IV Analyze each leg separately on the form, below.

Leg under analysis			Cross-street data							
			Street: <u>Albemarle</u> Leg: <u>West</u>				Street: <u>Albemarle</u> Leg: <u>East</u>			
1 Designation	2 Adjusted ADT (1977-78)	3 Config- uration	4 Adjusted ADT (1977-78)	5 Config- uration	6 Figure/ curve used	7 Hot spot indicated	8 Adjusted ADT (1977-78)	9 Config- uration	10 Figure/ curve used	11 Hot spot indicated
Wisconsin South	30K	4L-2W	6K	2L-2W	111-6/8	Yes	6K	2L-2W	111-6/8	Yes

Figure D-4. Completed screening worksheet

- the approximate geometry of the location
- the number of approach and departure lanes on each roadway if the site is an intersection, or just the number of lanes if the site is an expressway or mid-block location
- the width of each lane, shoulder, median, and channelizing island
- the locations within each site where curb parking is permitted, where bus stops and taxi stands are located, and the width of such parking lanes
- the location of the worst-case receptor site (as defined in the Guideline)
- pertinent notes regarding observations as to the operation of the facility.

The required data are generally obtained from field reconnaissance.

Figure D-5 shows the site sketch developed for the Wisconsin Avenue - Albemarle Street intersection.

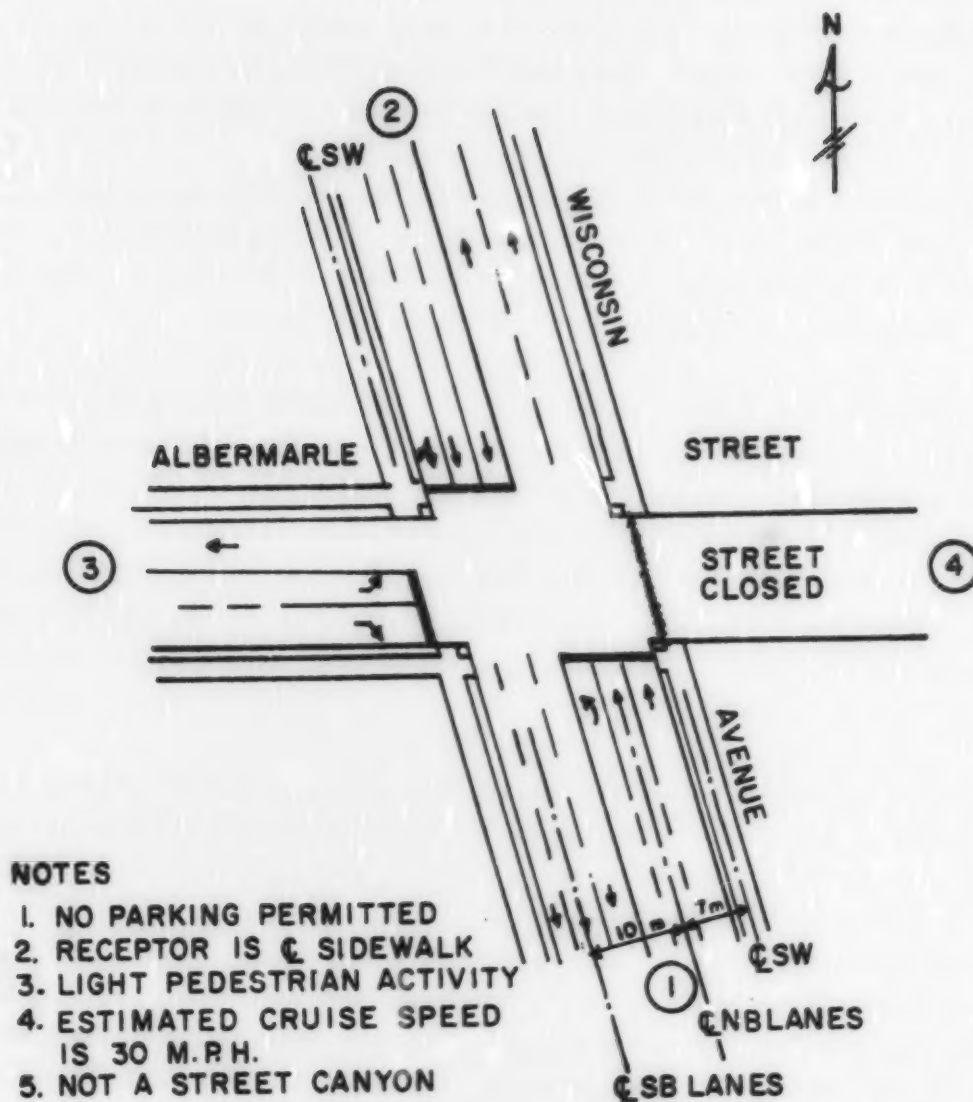


Figure D-5. Site sketch -- Wisconsin Avenue at Albemarle Street, N.W.

The next data element required is traffic volume data. For each location analyzed traffic volume data were provided by the Bureau of Traffic Engineering and Operations. The data consisted of summaries of turning movement counts taken for a 10-hour period during 1976. This summary for the Wisconsin Avenue - Albemarle Street intersection is reproduced in Table D-1.

Traffic speed estimates are required also. The Hot Spot Guidelines suggest that cruise speed information can be obtained for a location by conducting speed studies or from estimates based on guidance provided in the Guidelines. For this project, speeds were estimated.

Also required are traffic signal data. Of particular importance are the numbers of phases and the ratio of the green time allocated to each approach, to the total cycle length. These types of data are generally on file with the agency holding jurisdiction over a particular installation. Signal data for this study were obtained from the Bureau of Traffic Engineering and Operations. These data consisted of charts showing the phasing and timing for each signal and indicating the type of control used (i.e., fixed time or actuated, etc.).

Estimates of the vehicle-type distribution occurring on each roadway are required. For this project, it was assumed that the vehicle population consisted of 88 percent light-duty vehicles, 8 percent light-duty trucks, 3 percent heavy-duty gasoline-powered vehicles, and 1 percent heavy-duty diesel-powered vehicles. The fraction of vehicles operating in the cold-start mode and the hot start mode were also estimated. These estimates were that 5 percent of the vehicles using any roadway would be operating in the cold mode and 10 percent would be in the hot-start mode.

These data elements were then used in conjunction with the various tables and graphs provided in the Guidelines to estimate the maximum 8-hour average concentration of carbon monoxide likely to occur at the intersection of Wisconsin Avenue and Albemarle Street. The completed worksheet for

Table D-1. 10-HOUR TURNING MOVEMENT COUNT SUMMARY - WISCONSIN AVENUE AT ALBEMARLE STREET, N.W.

Hour ending	Wisconsin Avenue						Albemarle Street			
	Northbound			Southbound			Eastbound			
	Left	Through	Right	Total	Left	Through	Right	Total	Left	Total
8 a.m.	23	595	-	618	-	1,373	10	1,383	33	109
9 a.m.	14	750	-	764	-	1,386	28	1,414	54	191
10 a.m.	35	786	-	821	-	920	22	942	45	106
11 a.m.	49	722	-	771	-	809	39	848	59	123
12 noon	82	844	-	926	-	856	42	898	60	140
2 p.m.	67	916	-	983	-	842	28	870	44	130
3 p.m.	97	819	-	916	-	895	54	949	60	129
4 p.m.	76	893	-	969	-	861	42	903	61	166
5 p.m.	29	991	-	1,020	-	881	31	912	64	132
6 p.m.	11	1,187	-	1,198	-	996	52	1,048	65	130
Total	483	8,503	-	8,986	-	9,819	348	10,167	545	1,356
										20,509

Source: District of Columbia Department of Transportation, Bureau of Traffic Engineering and Operations, counts taken 11 May 1976.

computing the estimate is provided below along with an annotated instruction sheet for completing the worksheet; several tables and graphs used in the computations are provided also.

WORKSHEET No. 2

Calculation of CO Concentration Along Roadways
With Interrupted Flow (Intersections)

	Main road		Crossroad	
	WISCONSIN		ALBEMARLE	
1. Site identification				
2. i - Intersection approach identification	1	2	3	4
3. n_i - Number of traffic lanes in approach i	3	3	2	-
4. x_i - Roadway/receptor separation (m)	7	17		
5. V_i - Peak-hour lane volume in each approach (veh/hr)	400	350	65	-
6. S_i - Cruise speed (mph) on each approach	30	30	30	-
7. a. Type of intersection (signalized or unsignalized)	SIGNALIZED			
b. For signalized intersections:				
i) $(G/Cy)_1$ - Green time/signal cycle ratio for approach 1	0.36			
ii) V_{cross} - Effective crossroad volume (veh/hr)		250		
8. L_q - Queue length on approach 1 (m)	40			
9. Q_e - Excess emission rate (g/m-sec)	0.01464			
10. $Q_{f,i}$ - Free-flow emission rate (g/m-sec)	0.00169	0.00148	0.00043	-
11. $\left(\frac{X_u}{Q}\right)_{e,i}$ - Normalized concentration contribution from excess emissions on approach i ($10^{-3}m^{-1}$)	960	235	80	-
12. Cde_i - Distance correction factor, excess emissions	1.10	0.95	1.00	-
13. $X_{e,i}$ - Concentration contribution from excess emissions on approach i (mg/m^3)	15.2	3.5	1.2	-
14. X_e - Total contribution from excess emissions (mg/m^3)	19.9			
15. $\left(\frac{X_u}{Q}\right)_{f,main}$ - Normalized concentration contribution from free-flow emissions on main roadway ($10^{-3}m^{-1}$)	380			

Figure D-6. Verification worksheet - Wisconsin Avenue at Albemarle Street, NW

	Main road	Crossroad
16. $\left(\frac{X_u}{Q}\right)_{f,cross}$ - Normalized concentration contribution from free-flow emission on crossroad ($10^{-3}m^{-1}$)		120
17. Cdf_1 - Distance correction factor, free-flow emissions	1.10	0.95
18. a. $X_{f,main}$ - Concentration contribution from free-flow emissions on main road (mg/m^3)	3.7	
b. $X_{f,cross}$ - Concentration contribution from free-flow emissions on crossroad (mg/m^3)		0.1
19. X_f - Total concentration from free-flow emissions (mg/m^3)	3.8	
20. $X_{(f+e)}$ - Total concentration, uncorrected (mg/m^3)	23.7	
21. Vehicle mix: a. P_{LDV} <u>88%</u> b. P_{LDT} <u>8%</u> c. P_{HDV-G} <u>3%</u> d. P_{HDV-D} <u>1%</u>		
22. Year/location/vehicle-type correction factor:		
Year <u>1977</u> Altitude (low or high) <u>Low</u> State (Calif. or other) <u>Other</u>		
a. C_{LDVcat} <u>0.07</u> b. C_{LDVnc} <u>0.69</u>		
c. C_{LDTcat} <u>0.20</u> d. C_{LDTnc} <u>0.86</u>		
e. C_{HDV-G} <u>3.62</u>		
f. C_{HDV-D} <u>0.53</u>		
23. Temperature/cold-start correction factor:		
a. Percent cold-starts <u>5%</u>		
b. Percent hot-starts <u>10%</u>		
c. Temperature ($^{\circ}F$) <u>30$^{\circ}F$</u>		
d. Ccs_{cat} <u>4.47</u>		
e. Ccs_{nc} <u>1.27</u>		
24. C_E - Total emission correction factor	1.32	
25. $X_{E,1-hr}$ - 1-hour average concentration resulting from vehicle emissions (mg/m^3)	31.7	

Figure D-6 (continued). Verification worksheet - Wisconsin Avenue at Albemarle Street, NW

26.	$\bar{x}_{E, 8\text{-hr}}$ - 8-hour average CO concentration (mg/m ³)	<u>22.2</u>
27.	$\bar{x}_{B, 8\text{-hr}}$ - 8-hour average background concentration (mg/m ³)	<u>3.6</u>
28.	$\bar{x}_{T, 8\text{-hr}}$ - Total CO concentration, 8-hour average (mg/m ³)	<u>25.8 mg/m³</u>
29.	$\bar{x}_{T, 8\text{-hr}}$ - Total CO concentration, 8-hour average (ppm)	<u>22.4 ppm</u>

Figure D-6 (continued). Verification worksheet - Wisconsin Avenue at Albemarle Street, NW

WORKSHEET NO. 2 EXPLANATION OF DATA AND OPERATIONS
USED TO GENERATE EACH LINE ENTRY*

1. *Intersection identification.* Enter street names; instructions for identifying the main street are provided under Step 2, below.
2. *The pollutant concentration should be determined at the position where the maximum projected level is most likely to occur. The optimum receptor placement is determined according to the following guidelines.*
 - a. *The receptor should be located on an approach which has interrupted traffic flow.*
 - b. *If all such approaches to the intersection have an equal number of approach lanes, the receptor should be located on the approach having the highest peak hour volume.*
 - c. *If the approaches have an unequal number of lanes, and the approach having the greatest number of lanes also has the highest lane volume, the receptor should be located on that approach.*
 - d. *If the approach having the largest number of lanes does not have the greatest lane volume, Table D-2⁺ and Figure D-7⁺ must be used to determine receptor placement. The average cruise speed for the approaches must be known to use Table D-2. See Section IV.B.1.e of the Guidelines for aid in making this estimation.*

Enter Table D-2 using the lane volume of the approach having the most lanes as V_{main} to determine the queue length, L_q , which develops on that approach. Use this quantity to enter Figure D-7 to determine the normalized concentration, $(\chi u/Q)_g$. Next designate the largest lane volume as V_{main} and enter Table D-2 to determine the queue length which develops on the corresponding approach. Again use Figure D-7 to find the resulting normalized concentration $(\chi u/Q)_g$. The receptor should be located on the approach which yields the highest $(\chi u/Q)_g$ value.

* The actual instructions provided in the Guidelines are shown in italics; comments regarding the specific application to the example appear in regular type.

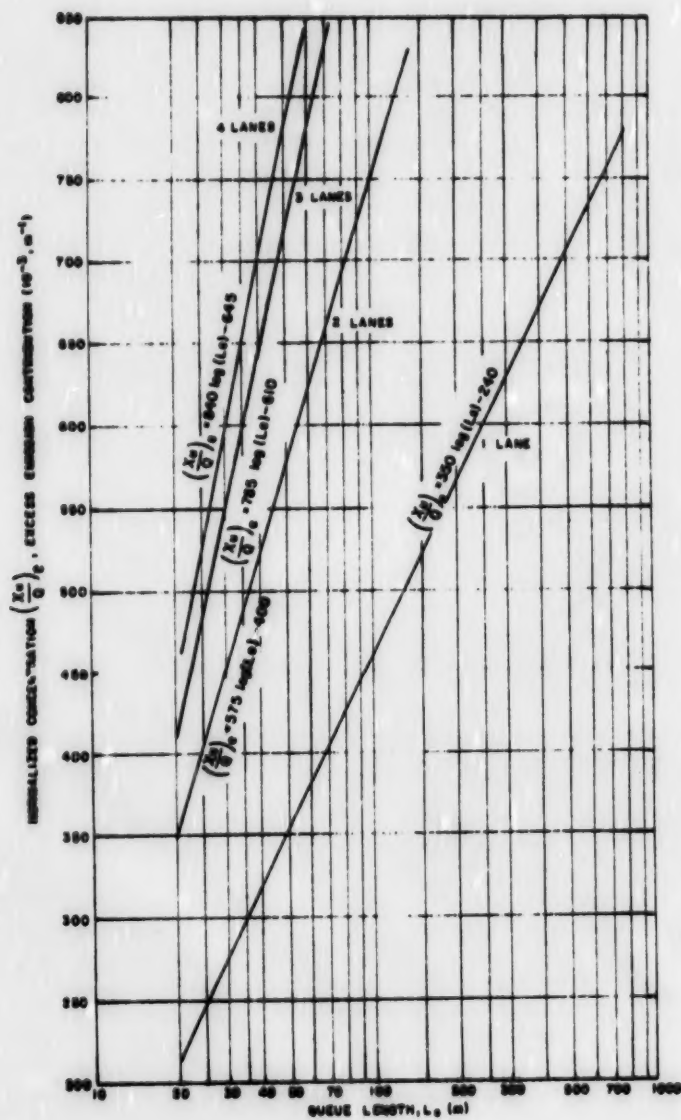
⁺ Table and Figure designations given here do not necessarily correspond to the designations in the Hot Spot Guidelines; the corresponding designation is noted on each table and figure provided here, however.

Table D-2. EXCESS EMISSIONS AND QUEUE LENGTHS AT SIGNALIZED INTERSECTIONS AS FUNCTIONS OF
MAXIMUM LANE VOLUME PER HOUR ON MAIN ROAD (HORIZONTAL AXIS) AND MAXIMUM LANE
VOLUME PER HOUR ON CROSSROAD (VERTICAL AXIS)^a

EXCESS EMISSIONS, CARBON DIOXIDE, AND NOX VOLUME LENGTH, THE CRUISE SPEED IS 30, MPH.		MAXIMUM LANE VOLUME PER HOUR ON CROSSROAD (VEHICLES/HOUR)															
1000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1500	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1200	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1100	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
900	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
800	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
700	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
600	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
500	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
400	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
300	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
200	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
100	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

MAXIMUM LANE VOLUME PER HOUR ON MAIN ROAD (VEHICLES/HOUR)

^a Appears as Table IV-2 in the Guidelines.



Note: Figure IV-3 in HSG.

Figure D-7. CO concentration contribution from excess emissions on approach 1 as a function of number of lanes and queue length

For this application, paragraph c applies. This is evident upon examining the site sketch (Figure D-5) and the traffic volume data shown in Table D-1. The highest hourly volume through the intersection occurs during the period from 5 p.m. to 6 p.m. During this period the volumes occurring on the northbound and southbound approaches of Wisconsin Avenue were 1198 and 1048 vehicles, respectively, while on Albemarle Street the volume was 130 vehicles. The average lane volume for these approaches, then, are 399 northbound, 349 southbound, and 65 on Albemarle. Therefore, by paragraph c, the receptor should be located on the east side of the northbound approach of Wisconsin Avenue. Wisconsin Avenue, then, is the main street while Albemarle is designated the cross street.

Each traffic stream (all lanes in one direction of travel) approaching the intersection should be assigned an identification number with regard to the receptor site as depicted below:



The assigned identification numbers are shown on the intersection sketch shown in Figure D-5.

3. Enter the number of lanes per each intersection approach.

This information is obtained from the site sketch in Figure D-5.

4. Enter the roadway/receptor separation distance, x_i , for approaches 1 and 2. This is the minimum perpendicular distance in meters from the centerline of the traffic stream approaching the intersection to a line parallel to the roadway drawn through the receptor site.

This information is obtained from the site sketch in Figure D-5.

5. Enter the peak-hour traffic volume per lane, V_i (vehicles/hour) for each intersection approach. This is the total traffic stream volume divided by the number of approach lanes.

As indicated in step 2, the peak hour occurs between 5 p.m. and 6 p.m. The lane volumes for Wisconsin Avenue are 400 vehicles per lane northbound, 350 vehicles per lane southbound; on Albemarle Street, the lane volumes are 65 vehicles per lane.

6. Enter the roadway cruise speed, S_i (mph), for each intersection approach.

As indicated previously, the cruise speed through the intersection was estimated to be 30 mph.

7. a. Enter type of intersection (signalized, stop or yield).

Traffic signals are used at this intersection.

- b. For signalized intersections:

- i) Enter the ratio of green time to total signal cycle length $(G/Cy)_1$ allocated to approach 1. Include time allocated for any pedestrian walk phases with no traffic movement in the total cycle length.

This information was provided by the District of Columbia Department of Transportation Bureau of Traffic Engineering and Operations.

- ii) Determine the effective crossroad volume, V_{cross} , using the following equation:

$$V_{cross} = \frac{\text{line 5}}{\text{line 7.b.i} + 0.05} - \text{line 5}$$

$$\text{For this intersection, } V_{cross} = \left[\left(\frac{400}{0.56 + 0.05} \right) - (400) \right] = 250$$

8. Determine the queue length, L_e (m), which develops on approach 1 as follows:

For signalized intersections use the appropriate section of Table D-2 based on cruise speed S_1 (line 6). Enter the table using $V_{main} = V_i$ (line 5) and $V_{cross} = \text{line 7.b.ii}$.

Queue length for approach 1 is 40 meters (from Table D-2).

9. Enter the corresponding excess emission rate, Q_e (g/m-sec), from Table D-2.

This value is obtained by interpolating between 0.01264 and 0.01665, which reflect values for crossroad volumes of 200 and 300 vehicles, respectively; since the crossroad volume is 250, the interpolation yields:

$$[(0.01665 - 0.01264)(0.5)] + 0.01264 = 0.01464$$

10. Enter the free-flow emission rate, Qf_i (g/m-sec), for each traffic stream using Table D-3. Enter the table using line 6i (cruise speed) and line 5 (average lane volume) for each approach.

The values obtained for approaches 1, 2 and 3 are 0.00169, 0.00148, and 0.0003, respectively.

11. Determine the normalized concentration contribution from excess emissions, $(xu/Q)_{e,i}$ for each approach as follows:

- a. The contribution from approach 1:

Enter Figure D-8 at the appropriate queue length, L_e (line 8), to obtain $(xu/Q)_{e,1}$. Multiply this value by the number of traffic lanes in approach 1 (line 3), and record result.

For approach 1, (Wisconsin Avenue northbound), the value is $320 \times 3 = 960$.

- b. The contribution from approach 2:

Enter Figure D-9, curve 2, at the same L_e , used in part (a), (line 8), to obtain $(xu/Q)_{e,2}$. Multiply this value by the number of traffic lanes in approach 2 (line 3), and record result.

For approach 2 (Wisconsin Avenue southbound) the value is $85 \times 3 = 255$

- c. The contribution from approach 3:

Signalized intersections - Enter Figure D-9, curve 3 at L_e (line 8) to obtain $(xu/Q)_{e,3}$. Multiply by the number of traffic lanes in approach 3 (line 3), and record result. Unsignalized intersections $(xu/Q)_{e,4} = 0$.

For approach 3 (Albemarle Street eastbound) the value is $40 \times 2 = 80$.

12. Determine the distance correction factors, Cde_i :

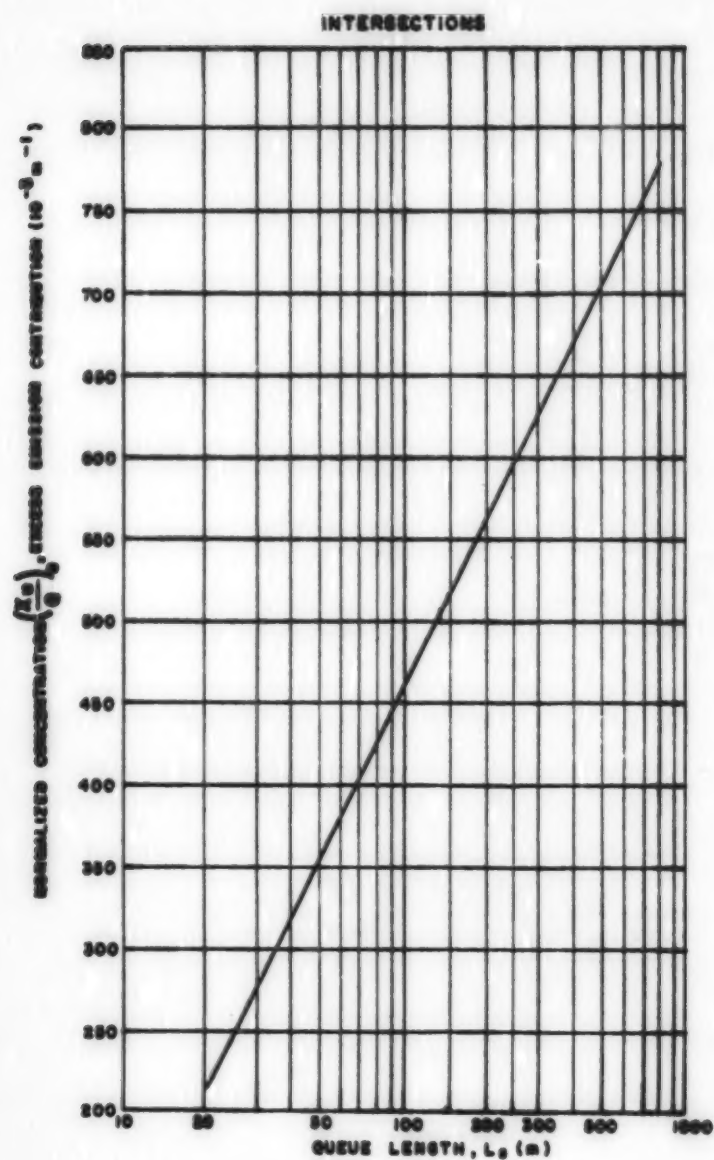
- a. Approach 1: obtain Cde_1 from Figure D-10 at the appropriate roadway/receptor separation distance x_1 (line 4).

Table D-3. FREE FLOW EMISSION RATE, Q_f , IN GRAMS PER METER-SECOND AS A FUNCTION OF LANE VOLUME AND VEHICLE SPEED ON ROADWAYS WITH INTERRUPTED FLOW (INTERSECTIONS)

CRUISE SPEED, mph	CRUISE EMISSIONS, GRAMS PER METER-SECOND														
	100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500
45	0.00035	0.00071	0.00106	0.00141	0.00177	0.00212	0.00247	0.00283	0.00318	0.00353	0.00389	0.00424	0.00459	0.00494	0.00529
40	0.00036	0.00073	0.00109	0.00145	0.00182	0.00218	0.00254	0.00291	0.00327	0.00363	0.00400	0.00436	0.00473	0.00509	0.00545
35	0.00036	0.00077	0.00115	0.00154	0.00192	0.00231	0.00269	0.00308	0.00346	0.00384	0.00423	0.00461	0.00500	0.00538	0.00576
30	0.00042	0.00084	0.00126	0.00169	0.00211	0.00253	0.00295	0.00337	0.00379	0.00421	0.00463	0.00504	0.00546	0.00588	0.00630
25	0.00048	0.00097	0.00145	0.00193	0.00242	0.00290	0.00339	0.00387	0.00435	0.00484	0.00532	0.00580	0.00629	0.00677	0.00725
20	0.00059	0.00116	0.00177	0.00236	0.00295	0.00354	0.00414	0.00473	0.00532	0.00591	0.00650	0.00709	0.00768	0.00827	0.00886
15	0.00079	0.00157	0.00236	0.00315	0.00394	0.00472	0.00551	0.00630	0.00709	0.00787	0.00866	0.00945	0.01023	0.01102	0.01181
	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+

TRAFFIC VOLUME FOR LANE (VEHICLES PER HOUR)

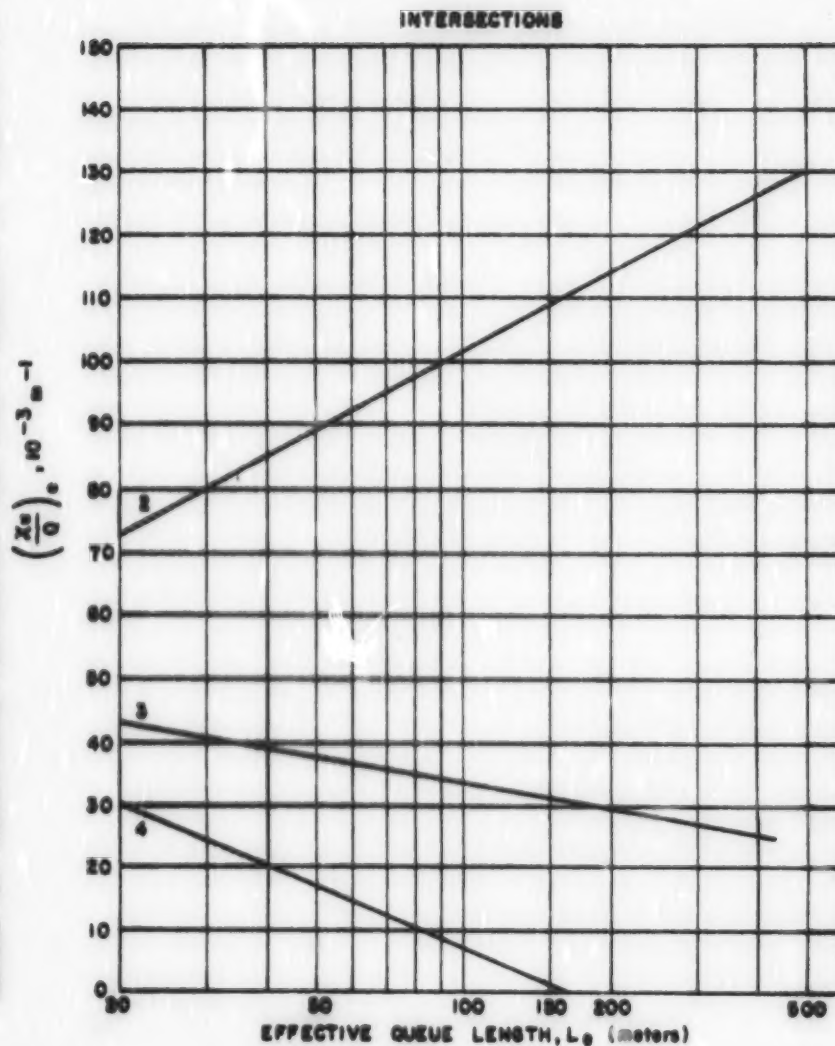
Note: Table IV-4 in HSG.



Note: Figure IV-4 in HSG.

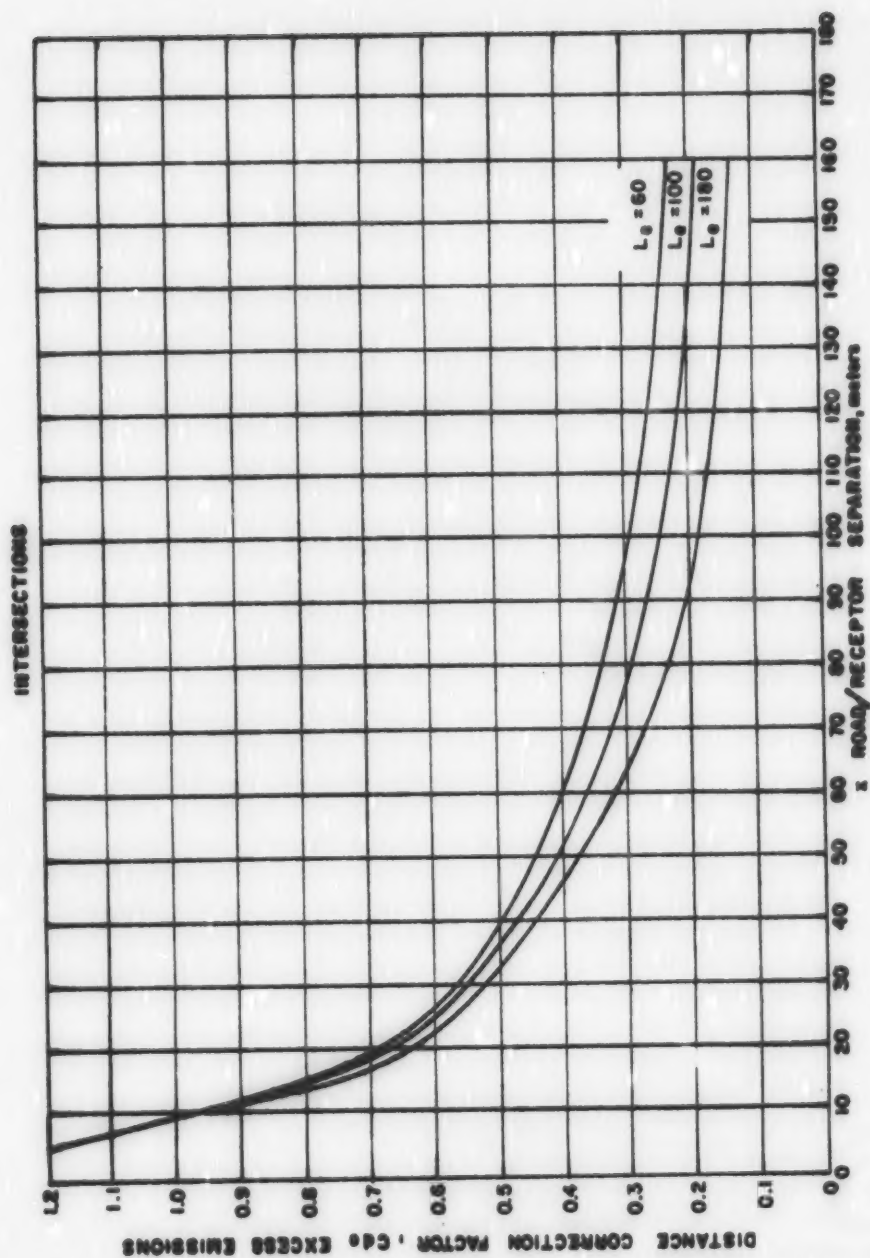
Figure D-8. Normalized CO concentration contribution from excess emissions on approach 1

NORMALIZED CONCENTRATION CONTRIBUTION FROM EXCESS EMISSIONS ON APPROACHES 2,3,4,



Note: Figure IV-5 in HSG.

Figure D-9. Normalized CO concentration contributions from excess emissions on approaches 2, 3, and 4



Note: Figure IV-8 in HSG.

Figure D-10. Distance correction factor for excess emission contributions at intersections

For approach 1, the x_1 value is 7 meters; from Figure D-10, the correction factor is 1.1.

- b. Approach 2: compute Cde_2 by dividing the value obtained from Figure D-10 at the appropriate distance x_2 (line 4) by 0.79:

$$Cde_2 = \frac{Cde \text{ (at } x_2)}{0.79}$$

For the approach 2, the x_2 value is 17 meters; from Figure D-10, the correction factor is: $0.75/0.79 = 0.95$.

- c. Approach 3: $Cde_3 = 1$ for signalized intersections.

13. Multiply (line 9) $\times$ (line 11)_i $\times$ (line 12)_i for all approaches to obtain the concentration, x_{ei} , at the receptor resulting from excess emissions on each approach.

For approach 1: $x_{e1} = (0.01464)(960)(1.1) = 15.5$

For approach 2: $x_{e2} = (0.01464)(255)(0.95) = 3.5$

For approach 3: $x_{e3} = (0.01464)(80)(1.0) = 1.2$

14. Sum all line 13 entries to obtain the total concentration, x_e , resulting from excess emissions at the intersection.

$$\sum_{i=1}^3 x_{ei} = 15.5 + 3.5 + 1.2 = 20.2$$

15. Enter Figure D-11 at the appropriate queue length, Le (line 8), and record the $(xu/Q)_f$ value using the curve designated MAIN ROAD.

$Le = 40$; therefore, from Figure D-11, $(xu/Q)_f = 380$

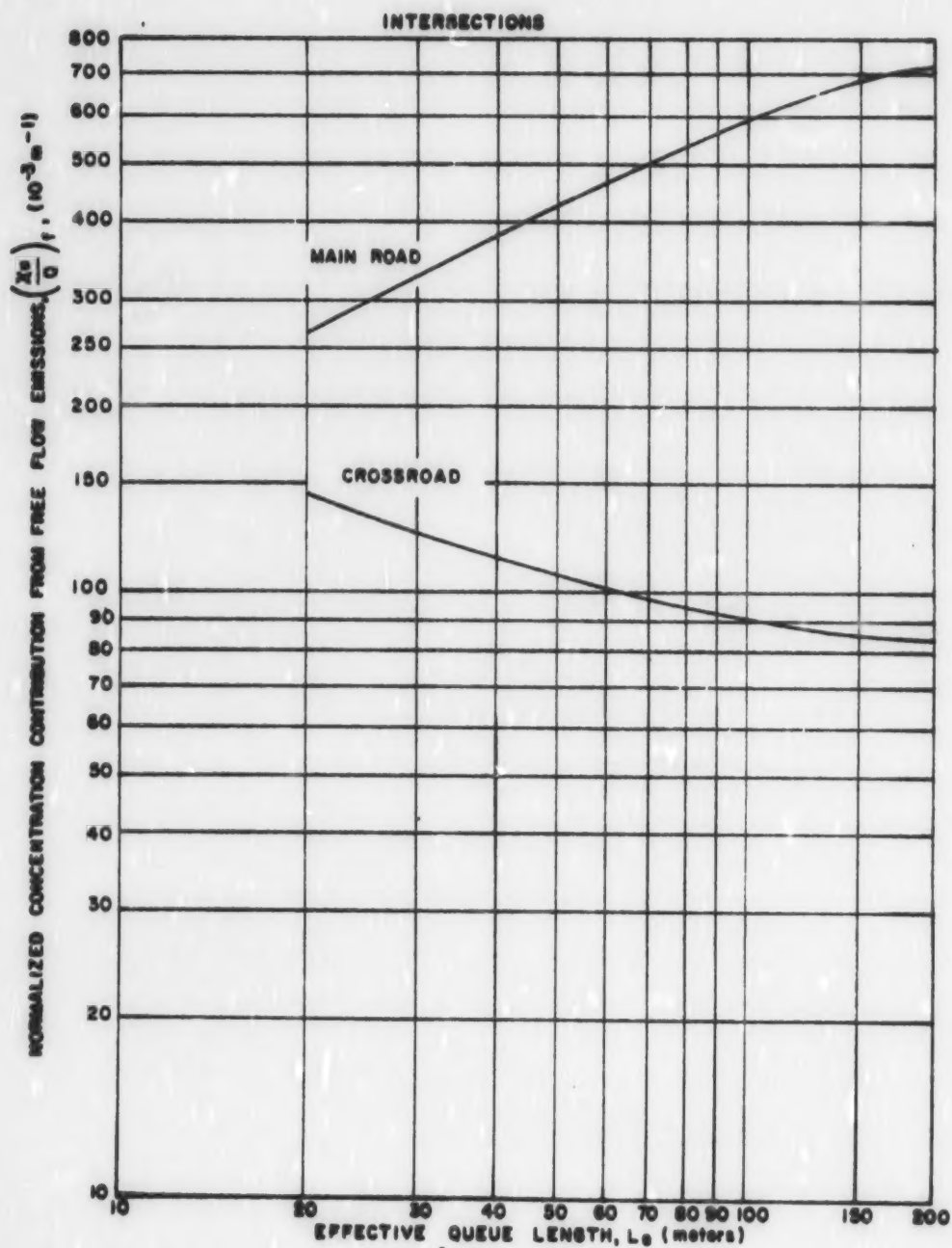
16. Similarly, determine the normalized concentration contribution from free-flow emissions on the crossroad, $(xu/Q)_{f, \text{cross}}$. Use the CROSSROAD curve of Figure D-11. Enter the graph at the same queue length as in step 15.

$Le = 40$; therefore, from Figure D-11, $(xu/Q)_{f, \text{cross}} = 120$

17. Enter the distance correction factors, Cdf_i , for free-flow emissions from the main roadway. Obtain these values from Figure D-12.

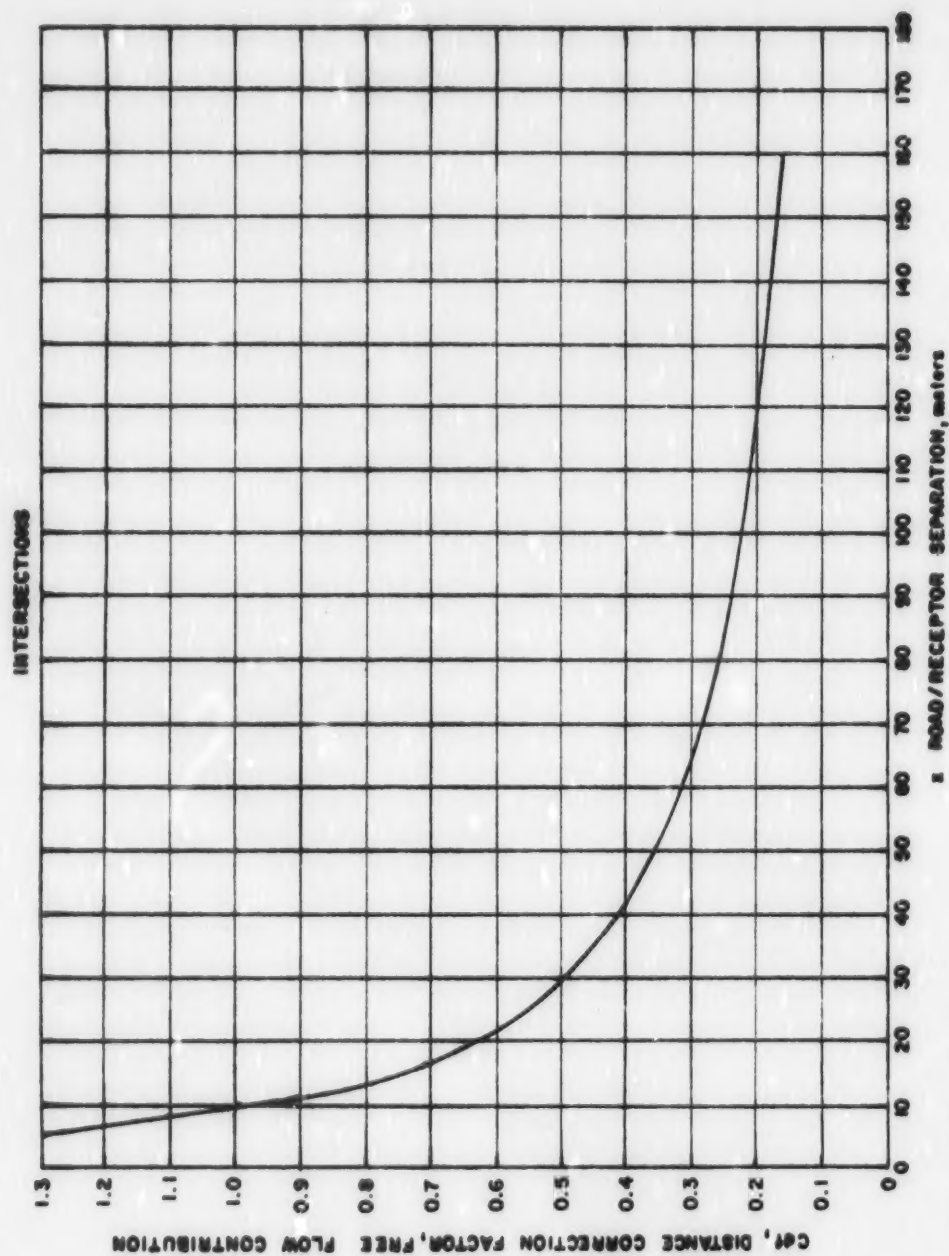
- a. Cdf_i is the correction factor at $x = x_i$ (line 7).

$x = x_1 = 7$ meters; therefore, from Figure D-12, $Cdf_1 = 1.1$



Note: Figure IV-7 in HSG.

Figure D-11. Normalized CO concentration contributions from free-flow emissions on each lane of roadways at intersections



Note: Figure IV-9 in HSG.

Figure D-12. Distance correction factor for free-flow emission contributions at intersection locations

- b. Cdf_2 is the correction factor for the departure lanes on leg 1, evaluated at x = the roadway/receptor separation distance for the departure stream. Usually this value is x_2 (line 4)₂.

$$x = x_2 = 17 \text{ meters; therefore, from Figure D-12, } Cdf_2 = 0.95$$

18. Compute the concentration contribution from free-flow emissions from each roadway, x_f .

$$\begin{aligned} a. \quad x_{f, \text{main}} &= \text{line 15} \quad (\text{line 3})_1 (\text{line 17})_1 (\text{line 10})_1 \\ &\quad + (\text{line 3})_2 (\text{line 17})_2 (\text{line 10})_2 \end{aligned}$$

$$x_{e, \text{main}} = (380) \quad (3)(1.1)(0.00169) + (3)(0.95)(0.00148) = 3.7$$

$$b. \quad x_{f, \text{cross}} = \text{line 16} \left[(\text{line 3})_3 (\text{line 10})_3 + (\text{line 3})_4 (\text{line 10})_4 \right]$$

$$x_{f, \text{cross}} = (120) \quad (2)(0.003) + (0.0)(0.0) = 0.1$$

19. Sum line 18 entries to obtain total contribution from free-flow emissions, x_f .

$$\Sigma x_f = x_{f, \text{main}} + x_{f, \text{cross}} = 3.7 + 0.1 = 3.8$$

20. Sum line 19 and line 14 to obtain the total CO concentration from intersection emissions, x_T , (uncorrected) at the receptor.

$$x_T = x_f + x_e = 3.8 + 20.2 = 24.0$$

21. Enter vehicle mix data - the relative proportions of light-duty vehicles (LDV), light-duty trucks (LDT), heavy-duty gasoline-fueled trucks (HDV-G), and heavy-duty diesel trucks (HDV-D).

As mentioned previously, the assumption was made that the vehicle fleet using any roadway would consist of 88 percent LDV's, 8 percent LDT's, 3 percent HDV-G's and 1 percent HDV-D's.

22. Enter the appropriate year/location correction factor for each vehicle type:

- $C_{LDVcat} = 0.07$ (from Table D-4)
- $C_{LDVnc} = 0.69$ (from Table D-4)
- $C_{LDTcat} = 0.20$ (from Table D-5)
- $C_{LDTnc} = 0.86$ (from Table D-5)

Table D-4. LIGHT-DUTY VEHICLE EMISSION CORRECTION FACTOR (BASE YEAR 1975) FOR CATALYST-EQUIPPED VEHICLES (C_{LDVcat}) AND NONEQUIPPED VEHICLES (C_{LDVnc})^a

Year	Low altitude, non-Calif.		High altitude, non-Calif.		Low altitude, Calif.		High altitude, Calif.	
	non-cat	cat	non-cat	cat	non-cat	cat	non-cat	cat
1975	0.98	0.02	1.71	0.04	0.98	0.01	1.71	0.02
1976	0.82	0.05	1.45	0.10	0.83	0.03	1.47	0.06
1977	0.69	0.07	1.23	0.13	0.69	0.04	1.23	0.07
1978	0.55	0.08	1.00	0.15	0.56	0.05	1.02	0.09
1979	0.44	0.09	0.81	0.15	0.44	0.06	0.81	0.10
1980	0.32	0.10	0.60	0.16	0.33	0.07	0.62	0.11
1985	0.06	0.09	0.12	0.11	0.05	0.08	0.10	0.10
1990	0	0.07	0	0.07	0	0.07	0	0.07

^aThese correction factors reflect the imposition of interim federal CO emission standards (for the low-altitude and high-altitude areas) through model year 1977 and the statutory standard thereafter. For California, the CO correction factors reflect the California interim standards through the 1977 model year and the statutory standards thereafter. Should amendments to the Clean Air Act proposed in March 1975 become law, correction factors for 1978 and later years may be altered. In the event Congress amends the Clean Air Act, this table should be altered accordingly. This may be done using Supplement 5 to AP-42 (Reference 2).

Note: Table IV-6 in HSG.

Table D-5. LIGHT-DUTY TRUCK EMISSION CORRECTION FACTOR (BASE YEAR 1975) FOR CATALYST-EQUIPPED TRUCKS (C_{LDTcat}) AND NONEQUIPPED TRUCKS (C_{LDTnc})

Year	Low altitude, non-Calif.		High altitude, non-Calif.		Low altitude, Calif.		High altitude, Calif.	
	non-cat	cat	non-cat	cat	non-cat	cat	non-cat	cat
1975	1.20	0.05	2.08	0.10	1.21	0.05	2.09	0.10
1976	1.03	0.12	1.79	0.26	1.03	0.12	1.80	0.26
1977	0.86	0.20	1.51	0.37	0.85	0.20	1.51	0.37
1978	0.71	0.24	1.25	0.41	0.71	0.24	1.25	0.41
1979	0.59	0.25	1.05	0.41	0.59	0.25	1.05	0.41
1980	0.43	0.26	0.80	0.39	0.43	0.26	0.80	0.39
1985	0.12	0.27	0.25	0.31	0.12	0.27	0.25	0.31
1990	0	0.26	0	0.26	0	0.26	0	0.26

Note: Table IV-7 in HSG.

Table D-6. HEAVY-DUTY GASOLINE-FUELED TRUCK EMISSION CORRECTION FACTOR (BASE YEAR 1975) (C_{HDV-G})

Year	Low altitude, non-Calif.	High altitude, non-Calif.	Low altitude, Calif.	High altitude, Calif.
1975	3.81	5.95	3.79	5.79
1976	3.71	5.83	3.66	5.75
1977	3.62	5.72	3.53	5.59
1978	3.49	5.62	3.39	5.46
1979	3.31	5.50	3.22	5.35
1980	3.02	5.27	2.94	5.13
1985	2.44	4.93	2.40	4.86
1990	2.13	4.85	2.13	4.85

Note: Table IV-8 in HSG.

Table D-7. HEAVY-DUTY DIESEL TRUCK EMISSION CORRECTION FACTOR (BASE YEAR 1975) (C_{HDV-D})

Year	Low altitude, non-Calif.	High altitude, non-Calif.	Low altitude, Calif.	High altitude, Calif.
1975-1990	0.53	0.53	0.53	0.53

Note: Table IV-9 in HSG.

e. $C_{\text{HDV-G}} = 3.62$ (from Table D-6)

f. $C_{\text{HDV-D}} = 0.53$ (from Table D-7)

Also, note that the evaluation year is 1977, Washington, D.C. is a low altitude city, and the city is located in an area other than California.

23. a. Enter present cold-starts.

This was estimated to be 5 percent.

- b. Enter percent hot-starts.

This was estimated to be 10 percent.

- c. Enter ambient temperature

This was assumed to be 30°F.

- d. Determine cold-start/temperature correction factor, C_{cat} , for catalyst-equipped vehicles from Table D-8.

$$C_{\text{cat}} = 4.47$$

- e. Determine cold-start/temperature correction factor, C_{nc} , for unequipped vehicles from Table D-9.

$$C_{\text{nc}} = 1.27$$

24. Compute the total emission correction factor, C_E , according to the following equation:

$$C_E = \text{line 21a} \left[(\text{line 23e})(\text{line 22b}) + (\text{line 23d})(\text{line 22a}) \right] \\ + \text{line 21b} \left[(\text{line 23e})(\text{line 22d}) + (\text{line 23d})(\text{line 22c}) \right] \\ + (\text{line 21c})(\text{line 22e}) + (\text{line 21d})(\text{line 22f})$$

$$C_E = (0.88) \left[(1.27)(0.98) + (4.47)(0.02) \right] + (0.08) \left[(1.27)(1.20) \right. \\ \left. + (4.47)(0.05) \right] + \left[(0.03)(3.81) \right] + \left[(0.01)(0.53) \right] = 1.32$$

25. Multiply line 24 by line 20 to obtain the corrected CO concentration.

$$\text{Corrected CO concentration} = 24.0 \times 1.32 = 31.7 \text{ mg/m}^3$$

Table D-8. COLD-START TEMPERATURE CORRECTION FACTORS
FOR CATALYST EQUIPPED LIGHT-DUTY VEHICLES
(LDV) AND LIGHT-DUTY TRUCKS (LDT)

% cold starts	Temperature °F						
	20	30	40	50	60	70	80
a. Assuming 10 percent hot-start operating vehicles							
0	1.21	1.21	1.21	1.22	1.22	1.22	1.23
10	10.48	7.72	5.77	4.39	3.43	2.76	2.28
20	19.75	14.21	10.32	7.57	5.64	4.30	3.33
30	29.01	20.72	14.87	10.75	7.85	5.04	4.37
40	38.28	27.22	19.42	13.93	10.06	7.38	5.42
b. Assuming 20 percent hot-start operating vehicles							
0	1.41	1.42	1.43	1.43	1.44	1.44	1.45
10	10.68	7.92	5.98	4.61	3.65	2.99	2.50
20	19.95	14.42	10.53	7.79	5.86	4.53	3.55
30	29.22	20.93	15.08	10.97	8.07	6.07	4.60
40	38.49	27.43	19.64	14.15	10.48	7.61	5.65
c. Assuming 30 percent hot-start operating vehicles							
0	1.62	1.63	1.64	1.65	1.66	1.67	1.68
10	10.89	8.13	6.19	4.83	3.87	3.21	2.73
20	20.16	14.63	10.74	8.00	5.98	4.75	3.78
30	29.43	21.14	15.30	11.18	8.29	6.29	4.83
40	38.70	27.64	19.85	14.36	10.49	7.83	5.87

Note: Table IV-11 in HSG.

Table D-9. COLD-START TEMPERATURE CORRECTION FACTOR FOR LDV's
AND LDT's NOT EQUIPPED WITH CATALYST (Ccs_{nc})

% Cold start	Temperature ($^{\circ}$ F)						
	20	30	40	50	60	70	80
0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
10	1.81	1.55	1.40	1.31	1.24	1.20	1.16
20	2.62	2.09	1.80	1.62	1.49	1.40	1.33
30	3.43	2.64	2.20	1.92	1.73	1.60	1.49
40	4.24	3.18	2.60	2.23	1.98	1.77	1.65
50	5.05	3.73	3.00	2.54	2.22	1.99	1.82
60	5.85	4.27	3.40	2.85	2.47	2.19	1.98
70	6.66	4.82	3.80	3.16	2.71	2.39	2.14
80	7.47	5.36	4.20	3.47	2.96	2.59	2.31
90	8.28	5.91	4.60	3.77	3.20	2.79	2.47
100	9.09	6.45	5.00	4.08	3.45	2.99	2.63

26. Multiply line 25 by 0.7 to obtain the highest expected 8-hour average concentration resulting from vehicle emissions.

$$\text{8-hour average concentration} = 31.7 \times 0.7 = 22.2 \text{ mg/m}^3$$

27. Enter 8-hour average background CO concentration in mg/m^3 . Assume 3.6 mg/m^3 if sufficient data to develop local background estimates are not available.

Local estimates were not available, therefore 3.6 mg/m^3 was assumed.

28. Sum lines 26 and 27 to obtain maximum expected 8-hour average concentration in the vicinity of the intersection (mg/m^3).

Maximum expected 8-hour average concentration expected is $22.2 \text{ mg/m}^3 + 3.6 \text{ mg/m}^3 = 25.8 \text{ mg/m}^3$ (22.4 ppm).

Hot Spot Modeling

A detailed discussion of the procedures used in exercising these Intersections Midblock Model will not be included here; rather, a description of the input data and its sources will be provided. For a comprehensive discussion of the application of the models, the reader should consult the User's Manual for the Intersection-Midblock Model.²

In order to apply the Intersection-Midblock Model, three basic data elements are required. The first is meteorological data reflecting both micro-and mesoscale conditions for the specific hours being analyzed. The specific elements required include average hourly wind speed and direction, and mixing height. These data were obtained from the summary of observations made at National Airport in Washington, D.C.

The second type of information required included traffic data. These included hourly volume on each lane, vehicle-type distribution, traffic signal data, cruise speed, and the percentage of vehicles operating in the cold mode. Volume data and traffic signal information were obtained from the District of Columbia Department of Transportation, Bureau of Traffic Engineering and Operations for the Wisconsin Avenue - Albemarle Street intersection, and from a report entitled Fairfax Air Quality Model³ for the Fairfax County site. The vehicle-type distributions and percentage of cold operating vehicles used in the verification procedure were also used in the modeling effort. Estimates of cruise speed were made based on field observations.

The third data element required concerned defining the physical and operating characteristics of each site. For the Wisconsin Avenue - Albemarle Street intersection, the site sketch developed for the verification phase, supplemented with additional data regarding the placement of the existing air quality monitor, was adequate for this application. A site sketch provided in Reference 3 was used for the Fairfax County Site. The streets were identified using a grid coordinate system to identify link endpoints

(nodes). Grid coordinates were also used to define the assumed receptor location; for both sites, the assumed receptor was placed at the actual monitor location.

These data provided the input required by the model to compute hourly average carbon monoxide concentrations resulting from emissions on the nearby highway system. A discussion of the actual results of the comparison of the modeled and measured concentrations is presented in Section IV.

REFERENCES

1. Guidelines for Identification and Evaluation of Localized Violations of Carbon Monoxide Standards. GCA/Technology Division, Bedford, Massachusetts. Prepared for U.S. Environmental Protection Agency, Research Triangle Park, N.C. Contract No. 68-02-1376.
2. User's Manual for the Intersection - Midblock Model. GCA/Technology Division, Bedford, Massachusetts. Prepared for U.S. Environmental Protection Agency, Research Triangle Park, N.C. Contract No. 68-02-1376 (Draft Final Report).
3. Fairfax Air Quality Model. Submitted to County of Fairfax, Office of Research and Statistics, Fairfax, Virginia by Engineering-Science, McLean, Virginia, in association with Howard Needles Tammen & Bergendoff, Alexandria, Virginia. November 18, 1976.

APPENDIX E

SAMPLE VERIFICATION WORKSHEETS

WORKSHEET No. 2

Calculation of CO Concentration Along Roadways
With Interrupted Flow (Intersections)

	Main road		Crossroad	
	Remo Ave		NEBRASKA Ave	NW
1. Site identification	1	2	3	4
2. i - Intersection approach identification	2	2	2	2
3. n_i - Number of traffic lanes in approach i	5	10		
4. x_i - Roadway/receptor separation (m)	530	330	500	250
5. V_i - Peak-hour lane volume in each approach (veh/hr)	35	35	35	35
6. S_i - Cruise speed (mph) on each approach				
7. a. Type of intersection (signalized or unsignalized)				
b. For signalized intersections:				
i) $(G/Cy)_1$ - Green time/signal cycle ratio for approach 1	0.52			
ii) V_{cross} - Effective crossroad volume (veh/hr)		400		
8. L_e - Queue length on approach 1 (m)	49			
9. Q_e - Excess emission rate (g/m-sec)	0.02472			
10. Qf_i - Free-flow emission rate (g/m-sec)	0.0021	0.00145	0.00192	0.00098
11. $\left(\frac{X_u}{Q}\right)_{e,i}$ - Normalized concentration contribution from excess emissions on approach i ($10^{-3}m^{-1}$)	700	176	76	34
12. Cde_i - Distance correction factor, excess emissions	1.15	1.25	1.0	1.0
13. $X_{e,i}$ - Concentration contribution from excess emissions on approach i (mg/m^3)	13.9	5.4	1.9	0.8
14. X_e - Total contribution from excess emissions (mg/m^3)	28.0			
15. $\left(\frac{X_u}{Q}\right)_{f,main}$ - Normalized concentration contribution from free-flow emissions on main roadway ($10^{-3}m^{-1}$)	410			

16. $\left(\frac{X_u}{Q}\right)_{f, \text{cross}}$ - Normalized concentration contribution from free-flow emission on crossroad (10^{-3}m^{-1})

17. Cdf_1 - Distance correction factor, free-flow emissions

18. a. $X_{f, \text{main}}$ - Concentration contribution from free-flow emissions on main road (mg/m^3)

b. $X_{f, \text{cross}}$ - Concentration contribution from free-flow emissions on crossroad (mg/m^3)

19. X_f - Total concentration from free-flow emissions (mg/m^3)

20. $X_{(f+e)}$ - Total concentration, uncorrected (mg/m^3)

21. Vehicle mix: a. P_{LDV} 88% b. P_{LDT} 8% c. P_{HDV-G} 3% d. P_{HDV-D} 1%

22. Year/location/vehicle-type correction factor:

Year 1977 Altitude (low or high) Low State (Calif. or other) Other

a. C_{LDVcat} 0.07 b. C_{LDVnc} 0.69

c. C_{LDTcat} 0.20 d. C_{LDTnc} 0.86

e. C_{HDV-G} 1.62

f. C_{HDV-D} 0.53

23. Temperature/cold-start correction factor:

a. Percent cold-starts 5%

b. Percent hot-starts 10%

c. Temperature ($^{\circ}\text{F}$) 30 $^{\circ}\text{F}$

d. $C_{cs_{cat}}$ 4.47

e. $C_{cs_{nc}}$ 1.27

24. C_E - Total emission correction factor

25. $X_{E, 1\text{-hr}}$ - 1-hour average concentration resulting from vehicle emissions (mg/m^3)

Main road | Crossroad

		1/0
1.15	1.25	
3.3		
		0.6

3.9

31.9

1.32

42.1

26.	$\bar{x}_{E, 8\text{-hr}}$ - 8-hour average CO concentration (mg/m^3)	<u>29.5</u>
27.	$\bar{x}_{B, 8\text{-hr}}$ - 8-hour average background concentration (mg/m^3)	<u>3.6</u>
28.	$\bar{x}_{T, 8\text{-hr}}$ - Total CO concentration, 8-hour average (mg/m^3)	<u>33.1</u>
29.	$\bar{x}_{T, 8\text{-hr}}$ - Total CO concentration, 8-hour average (ppm)	<u>28.8</u>

WORKSHEET No. 2

Calculation of CO Concentration Along Roadways
With Interrupted Flow (Intersections)

	Main road		Crossroad	
	4 th St		E St	NW
1. Site identification	1W	2	3	4
2. i - Intersection approach identification	2	2	2	-
3. n _i - Number of traffic lanes in approach i	6	13		
4. x _i - Roadway/receptor separation (m)	280	200	150	-
5. V _i - Peak-hour lane volume in each approach (veh/hr)	30	30	30	30
6. S _i - Cruise speed (mph) on each approach				
7. a. Type of intersection (signalized or unsignalized)				
b. For signalized intersections:				
i) (G/Cy) _i - Green time/signal cycle ratio for approach i	0.55			
ii) V _{cross} - Effective crossroad volume (veh/hr)		190		
8. L _e - Queue length on approach i (m)	40			
9. Q _e - Excess emission rate (g/m-sec)	0.01			
10. Q _{f,i} - Free-flow emission rate (g/m-sec)	0.0012	0.0004	0.0063	-
11. $\left(\frac{x_i}{Q}\right)_{e,i}$ - Normalized concentration contribution from excess emissions on approach i (10 ⁻³ m ⁻¹)	640	170	80	-
12. C _{de,i} - Distance correction factor, excess emissions	1.1	1.1	1.0	1.0
13. x _{e,i} - Concentration contribution from excess emissions on approach i (mg/m ³)	7.0	1.8	0.8	-
14. x _e - Total contribution from excess emissions (mg/m ³)	9.6			
15. $\left(\frac{x_i}{Q}\right)_{f,\text{main}}$ - Normalized concentration contribution from free-flow emissions on main roadway (10 ⁻³ m ⁻¹)	380			

16. $\left(\frac{X_u}{Q}\right)_{f, \text{cross}}$ - Normalized concentration contribution from free-flow emission on crossroad (10^{-3} m^{-1})

Main road	Crossroad
	120
1.1	
1.7	
	0.2

17. Cdf_1 - Distance correction factor, free-flow emissions

18. a. $X_{f, \text{main}}$ - Concentration contribution from free-flow emissions on main road (mg/m^3)

- b. $X_{f, \text{cross}}$ - Concentration contribution from free-flow emissions on crossroad (mg/m^3)

19. X_f - Total concentration from free-flow emissions (mg/m^3)

20. $X_{(f+s)}$ - Total concentration, uncorrected (mg/m^3)

21. Vehicle mix: a. P_{LDV} 88% b. P_{LDT} 8% c. P_{HDV-G} 3% d. P_{HDV-D} 1%

22. Year/location/vehicle-type correction factor:

Year 1977 Altitude (low or high) Low State (Calif. or other) Other

a. C_{LDVcat} 0.07 b. C_{LDVnc} 0.69

c. C_{LDTcat} 0.20 d. C_{LDTnc} 0.86

e. C_{HDV-G} 3.62

f. C_{HDV-D} 0.53

23. Temperature/cold-start correction factor:

a. Percent cold-starts 5%

b. Percent hot-starts 10%

c. Temperature ($^{\circ}\text{F}$) 30 $^{\circ}\text{F}$

d. $C_{cs_{cat}}$ 4.47

e. $C_{cs_{nc}}$ 1.27

24. C_E - Total emission correction factor

25. $X_{E, 1\text{-hr}}$ - 1-hour average concentration resulting from vehicle emissions (mg/m^3)

26.	$\chi_{E, 8\text{-hr}}$ - 8-hour average CO concentration (mg/m ³)	<u>10.6</u>
27.	$\chi_{B, 8\text{-hr}}$ - 8-hour average background concentration (mg/m ³)	<u>3.6</u>
28.	$\chi_{T, 8\text{-hr}}$ - Total CO concentration, 8-hour average (mg/m ³)	<u>14.2</u>
29.	$\chi_{T, 8\text{-hr}}$ - Total CO concentration, 8-hour average (ppm)	<u>12.4</u>

WORKSHEET No. 2

**Calculation of CO Concentration Along Roadways
With Interrupted Flow (Intersections)**

	<u>Main road</u>		<u>Crossroad</u>	
	<u>S. DAKOTA Ave</u>		<u>Russell Island Ave NE</u>	
1. Site identification	1	2	3	4
2. i - Intersection approach identification	2	2	2	2
3. n_i - Number of traffic lanes in approach i	6	13		
4. x_i - Roadway/receptor separation (m)	700	600	650	400
5. V_i - Peak-hour lane volume in each approach (veh/hr)	35	35	35	35
6. S_i - Cruise speed (mph) on each approach				
7. a. Type of intersection (<u>signalized</u> or unsignalized)				
b. For signalized intersections:				
i) $(G/Cy)_i$ - Green time/signal cycle ratio for approach i	0.45			
ii) V_{cross} - Effective crossroad volume (veh/hr)		700		
8. L_e - Queue length on approach i (m)	177			
9. Q_e - Excess emission rate (g/m-sec)	0.01741			
10. Qf_i - Free-flow emission rate (g/m-sec)	0.00169	0.00231	0.00130	0.00154
11. $\left(\frac{x_u}{Q}\right)_{e,i}$ - Normalized concentration contribution from excess emissions on approach i ($10^{-3}m^{-1}$)	1100	225	60	0
12. Cde_i - Distance correction factor, excess emissions	1.1	1.1	1.0	1.0
13. $x_{e,i}$ - Concentration contribution from excess emissions on approach i (mg/m^3)	21.1	4.3	1.0	-
14. x_e - Total contribution from excess emissions (mg/m^3)	25.4			
15. $\left(\frac{x_u}{Q}\right)_{f,main}$ - Normalized concentration contribution from free-flow emissions on main roadway ($10^{-3}m^{-1}$)	700			

	Main road	Crossroad
16. $\left(\frac{X_u}{Q}\right)_{f,cross}$ - Normalized concentration contribution from free-flow emission on crossroad ($10^{-3}m^{-1}$)		85
17. Cdf_1 - Distance correction factor, free-flow emissions	1.1	1.1
18. a. $X_{f,main}$ - Concentration contribution from free-flow emissions on main road (mg/m^3)	7.7	
b. $X_{f,cross}$ - Concentration contribution from free-flow emissions on crossroad (mg/m^3)		0.7
19. X_f - Total concentration from free-flow emissions (mg/m^3)	8.4	
20. $X_{(f+e)}$ - Total concentration, uncorrected (mg/m^3)	33.8	
21. Vehicle mix: a. P_{LDV} 88% b. P_{LDT} 8% c. P_{HDV-G} 3% d. P_{HDV-D} 1%		
22. Year/location/vehicle-type correction factor:		
Year 1977 Altitude (low or high) Low State (Calif. or other) Other		
a. C_{LDVcat} 0.07 b. C_{LDVnc} 0.69		
c. C_{LDTcat} 0.20 d. C_{LDTnc} 0.86		
e. C_{HDV-G} 3.62		
f. C_{HDV-D} 0.53		
23. Temperature/cold-start correction factor:		
a. Percent cold-starts 5%		
b. Percent hot-starts 10%		
c. Temperature ($^{\circ}F$) 30 $^{\circ}F$		
d. Ccs_{cat} 4.47		
e. Ccs_{nc} 1.27		
24. C_E - Total emission correction factor	1.32	
25. $X_{E,1-hr}$ - 1-hour average concentration resulting from vehicle emissions (mg/m^3)	44.6	

26.	$\chi_{E, 8\text{-hr}}$	- 8-hour average CO concentration (mg/m ³)	<u>31.2</u>
27.	$\chi_{B, 8\text{-hr}}$	- 8-hour average background concentration (mg/m ³)	<u>3.6</u>
28.	$\chi_{T, 8\text{-hr}}$	- Total CO concentration, 8-hour average (mg/m ³)	<u>34.8</u>
29.	$\chi_{T, 8\text{-hr}}$	- Total CO concentration, 8-hour average (ppm)	<u>30.3</u>